METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 61 No. 365 MARCH, 1960 Monthly: Two Shillings and Sixpence


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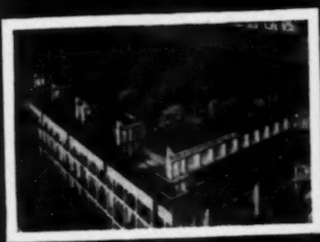


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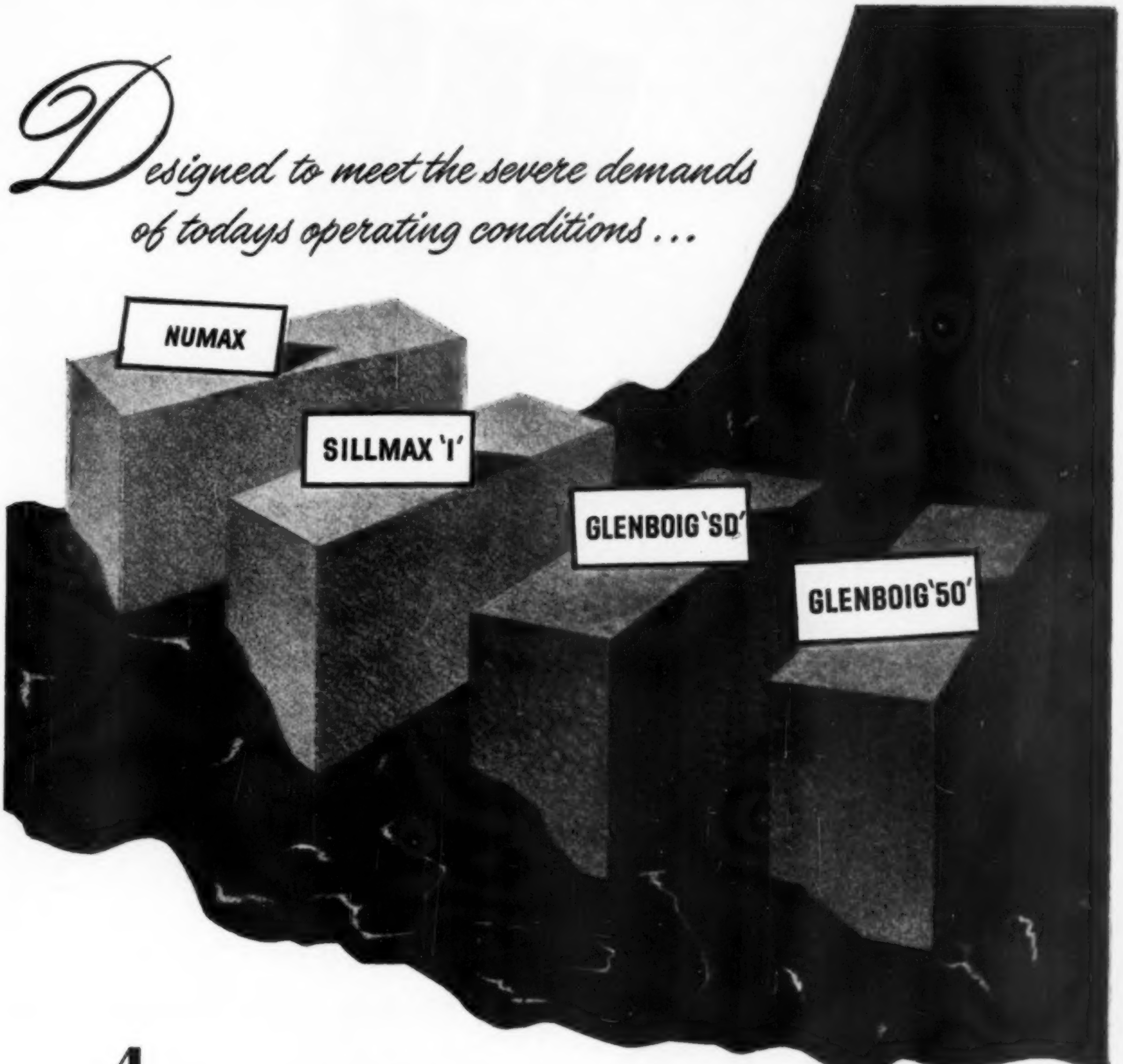

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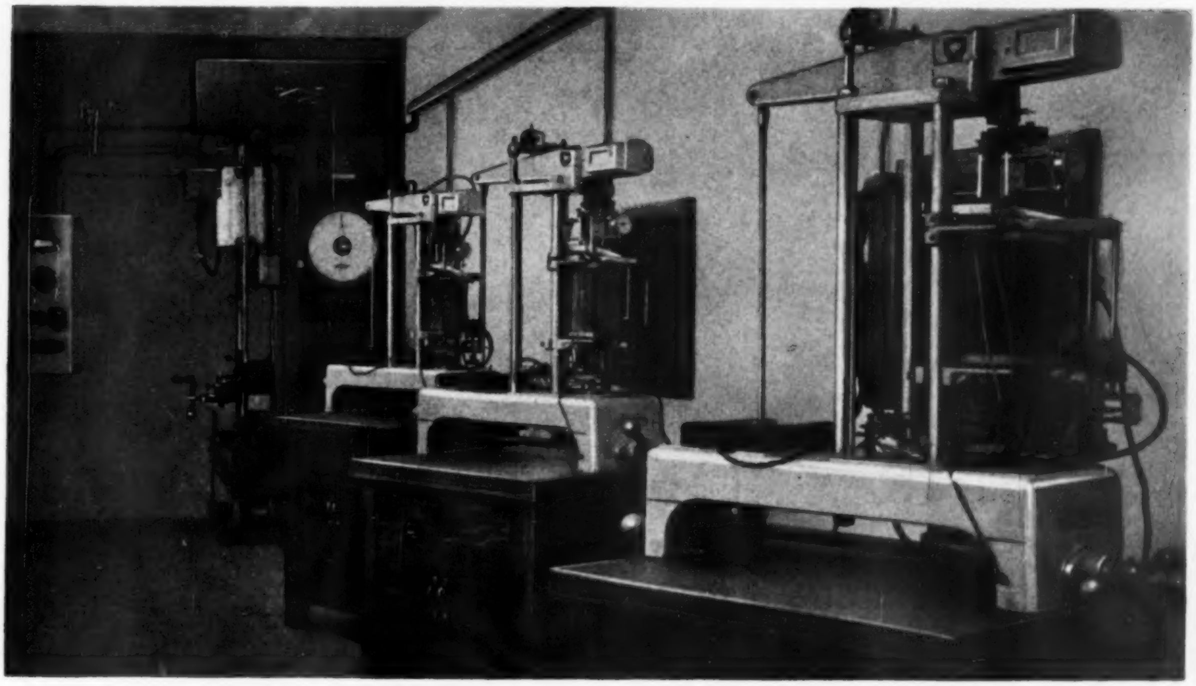

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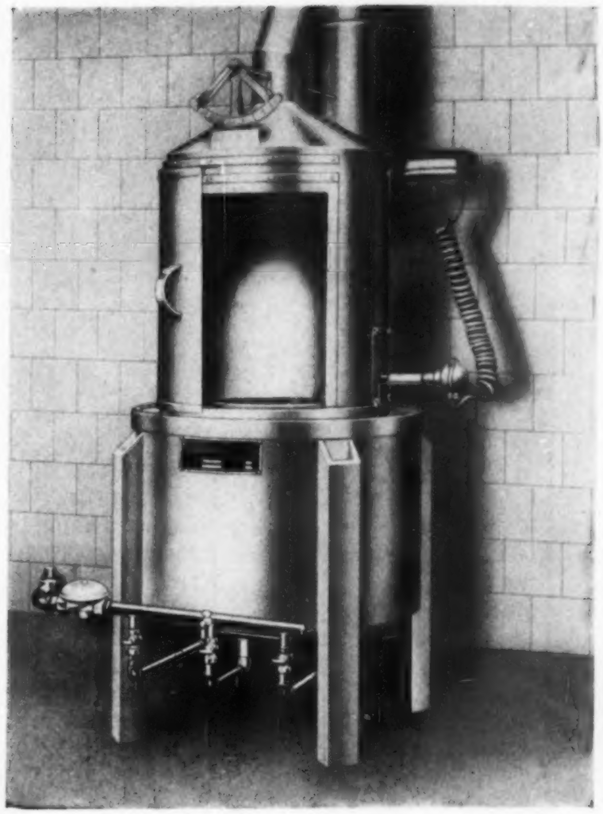

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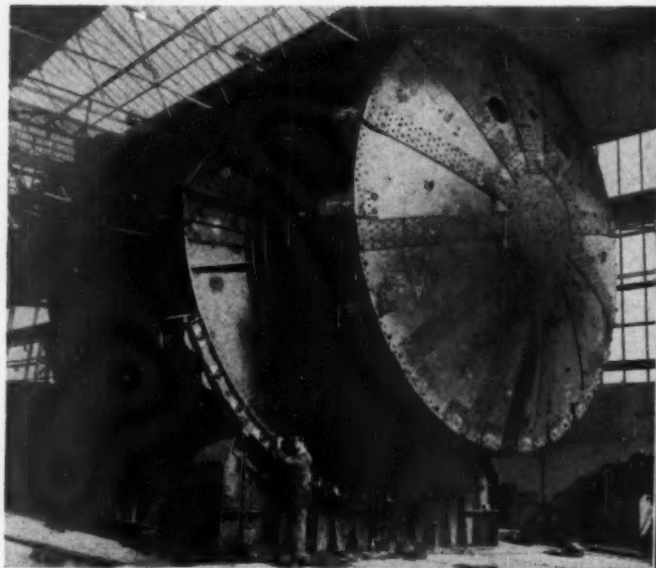

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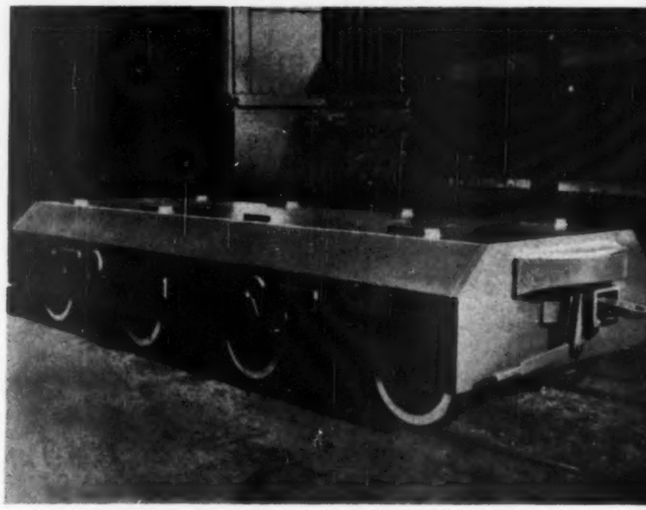

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The orders were completed well ahead of schedule.

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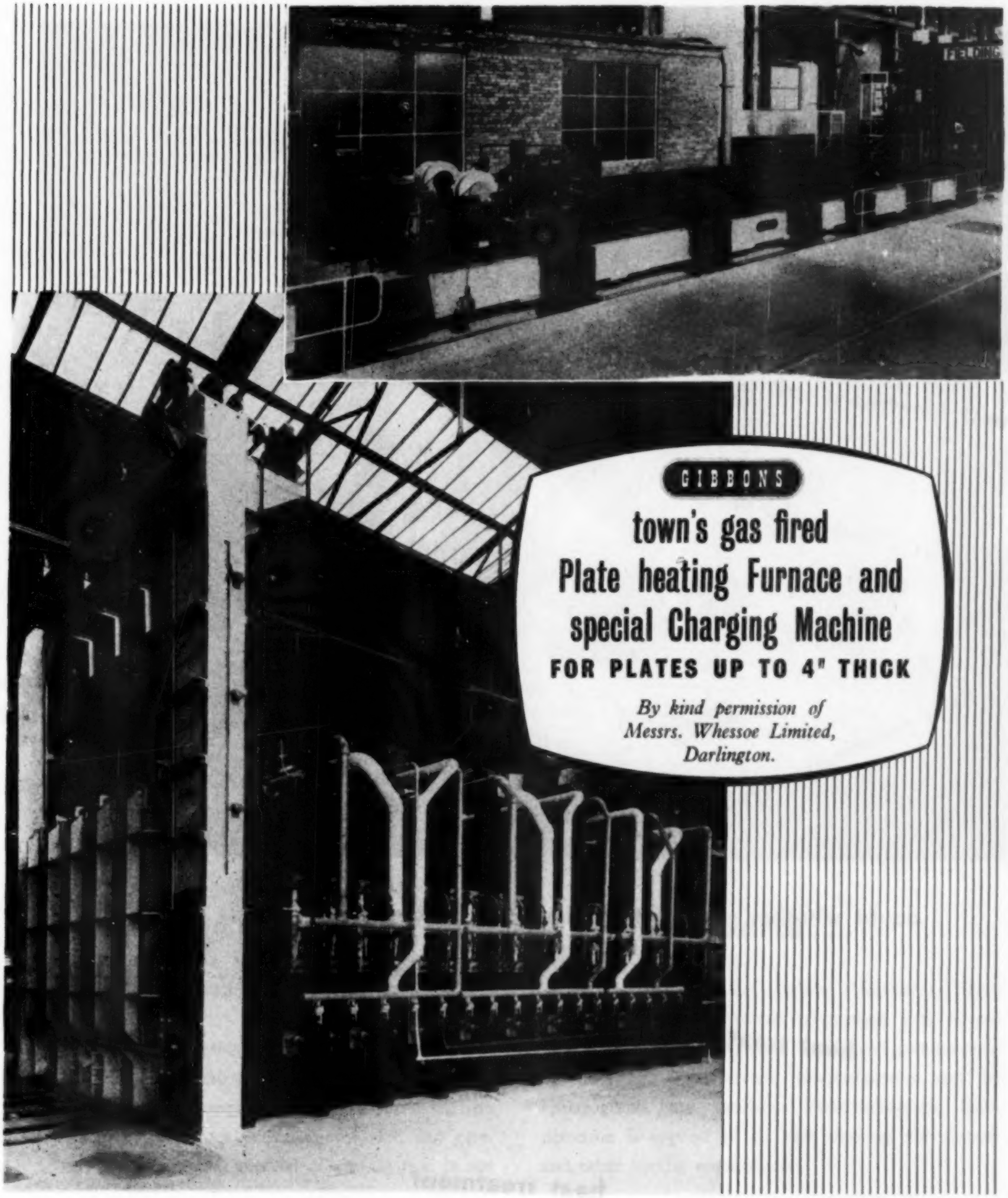

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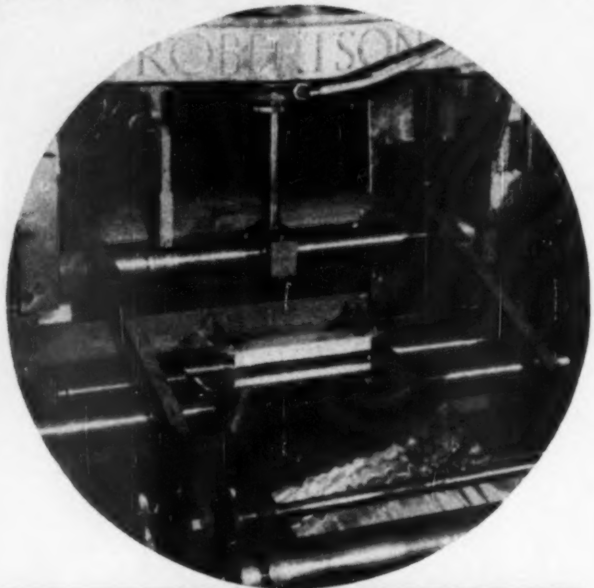
ACCURATE, CONTINUOUS, NON-CONTACT INSPECTION

SAVES MATERIAL, LABOUR AND TIME!



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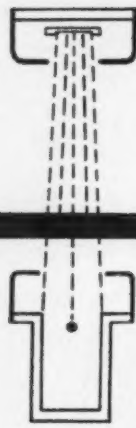
RAY SOURCE
MATERIAL
RAY DETECTOR
Amount of rays passing through material indicates thickness or weight per unit area.

That's the very basic explanation of the Atomat principle. There are three main gauges; the Atomat Cold Strip Gauge, the Hot Strip Gauge and the Beta Gauge.
In addition there are special purpose variations, made to meet the requirements of many different industries.



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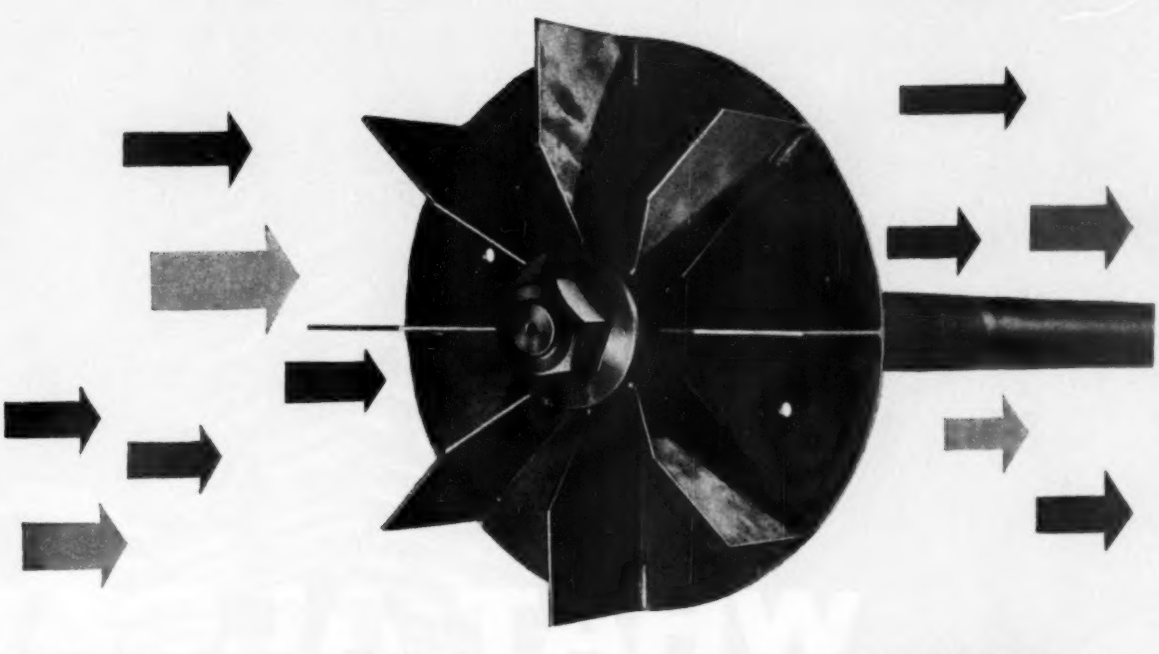
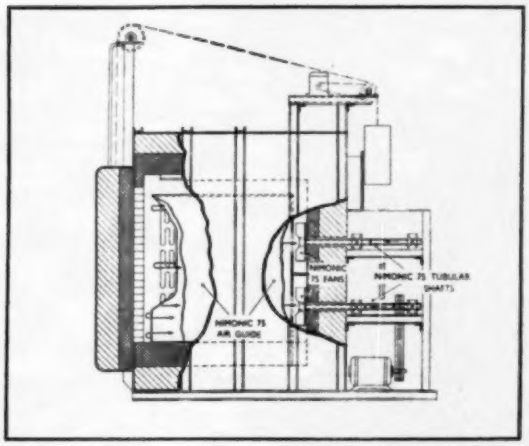


For furnace fans operating at 1100°C

-Nimonic* 75



HEAT-RESISTING ALLOY

A high-temperature electric furnace of advanced design has been developed by Hedin Limited, for the heat-treatment of components during the overhaul of Rolls-Royce 'Avon' and 'Conway' turbo-jet engines.

To ensure even heat distribution within the furnace, four centrifugal fans are required to operate continuously at temperatures up to 1100°C. The nickel-chromium alloy, Nimonic 75, was selected for the construction of the fans and their drive shafts. The excellent high-temperature properties of Nimonic 75 enable it to resist oxidation and withstand the exacting centrifugal stresses at extreme heat.

TOP
In addition to the forced-circulation fans and drive shafts, Nimonic 75 is used for the air-guide furnace liner which directs circulating air over the heating elements.

INSET
Diagram shows forced-circulation system and the Nimonic 75 hollow fan-shafts cooled by compressed air.

* Trade Mark

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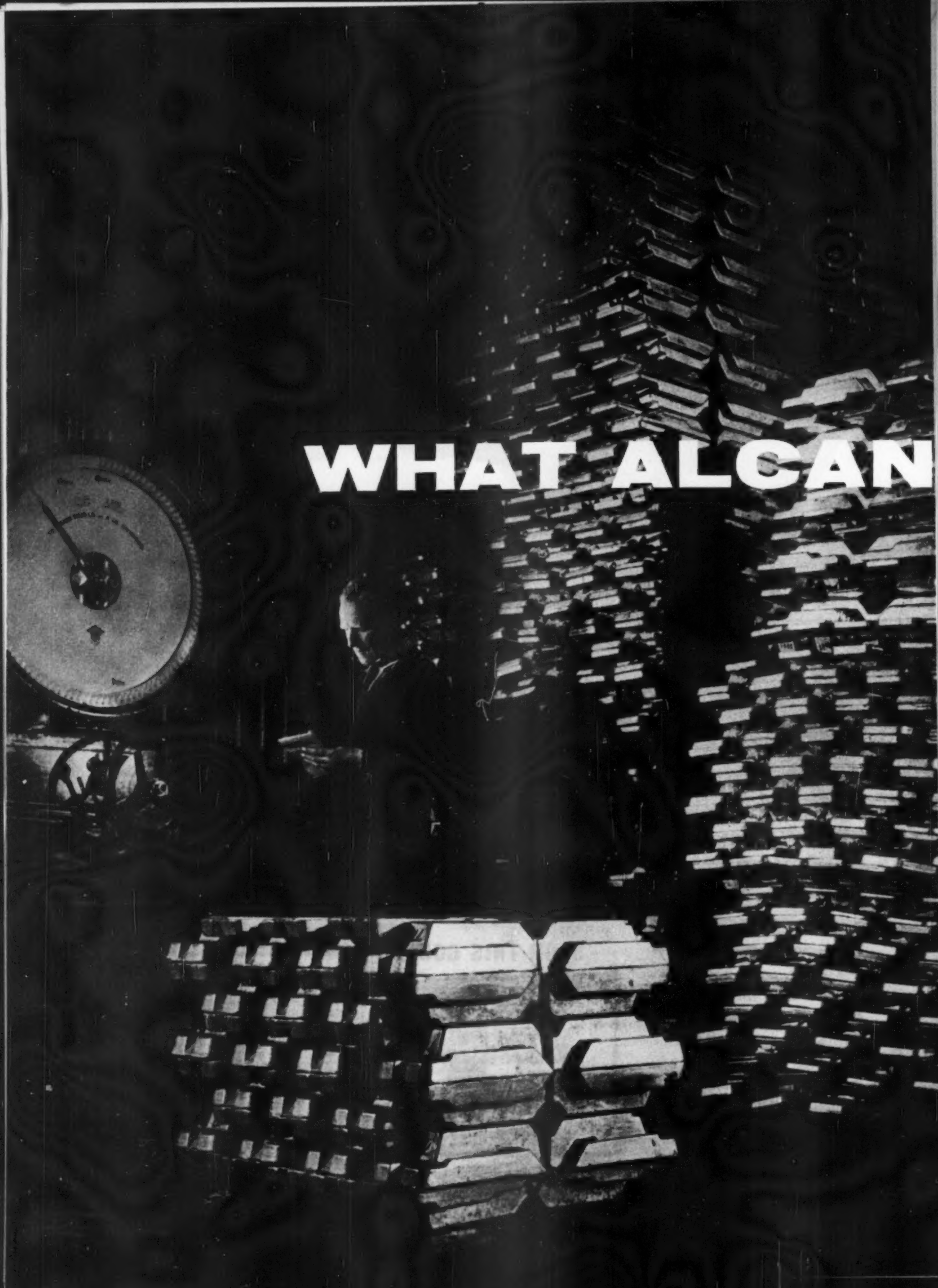
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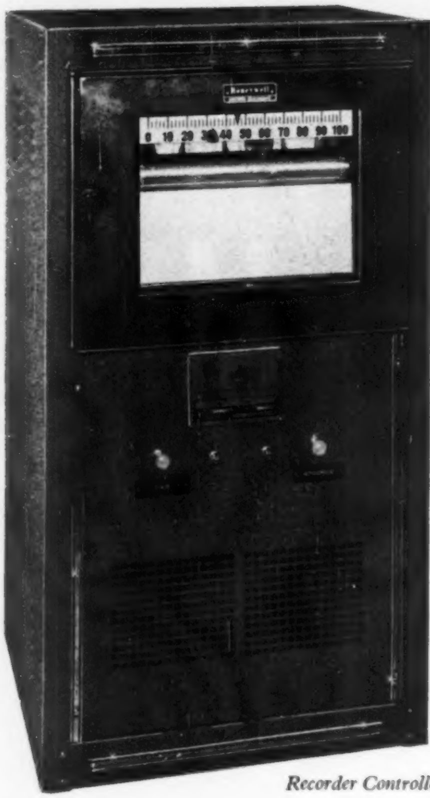

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Autocarb systems automatically adjust the flow of air or enriching hydrocarbon to the furnace or generator in direct response to the dew point of the atmosphere. Specified conditions are automatically maintained. Autocarb systems are simple compact units which indicate, record and control the dew point of gas atmospheres in continuous or batch furnaces and atmosphere generators. They can control dew points to within plus or minus two degrees. On continuous furnaces separate zones of atmosphere control can be established and automatically maintained. If manual control is preferred, the Autocarb line includes simple recorders or indicators. On batch furnaces the Autocarb system will maintain the desired carbon potential for each temperature established in the heating chamber. On endothermic gas generators Autocarb systems automatically and continuously compensate for fluctuations in the composition of the reaction fuel gas supply and the humidity of the reaction air. This keeps constant the dew point of the product gas.

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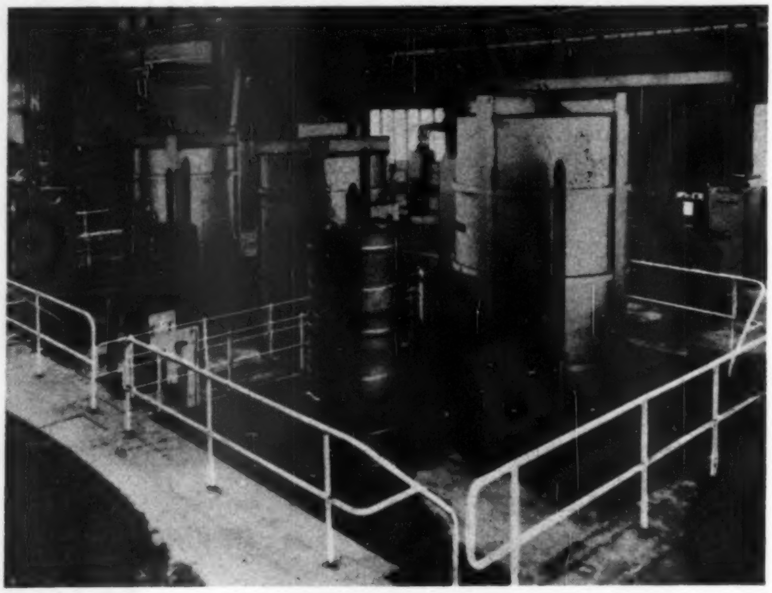
Electric Bell furnaces for heat treating stainless steels

SHEPCOTE LANE ROLLING MILLS SPECIFY G.W.B.



The only company in Great Britain specialising in the production of stainless steel coiled strip, Shepcote Lane Rolling Mills of Sheffield have to be confident that their heat-treatment is not only rigidly controlled but that a continuous seven-day-a-week output is maintained without furnace failure.

As production and the range of products have increased much new plant has been installed, among which are four G W.B. electrically heated bell furnaces. Hot rolling to a thickness of approximately .128″ from slabs of stainless steel weighing between 2 and 3 tons produces coils up to 54″ diameter and widths ranging from 24½″ to 40½″, and it is after hot rolling that softening in G.W.B. bell furnaces is carried out in order to remove residual hot rolling stresses prior to descaling and cold rolling to lighter gauges.

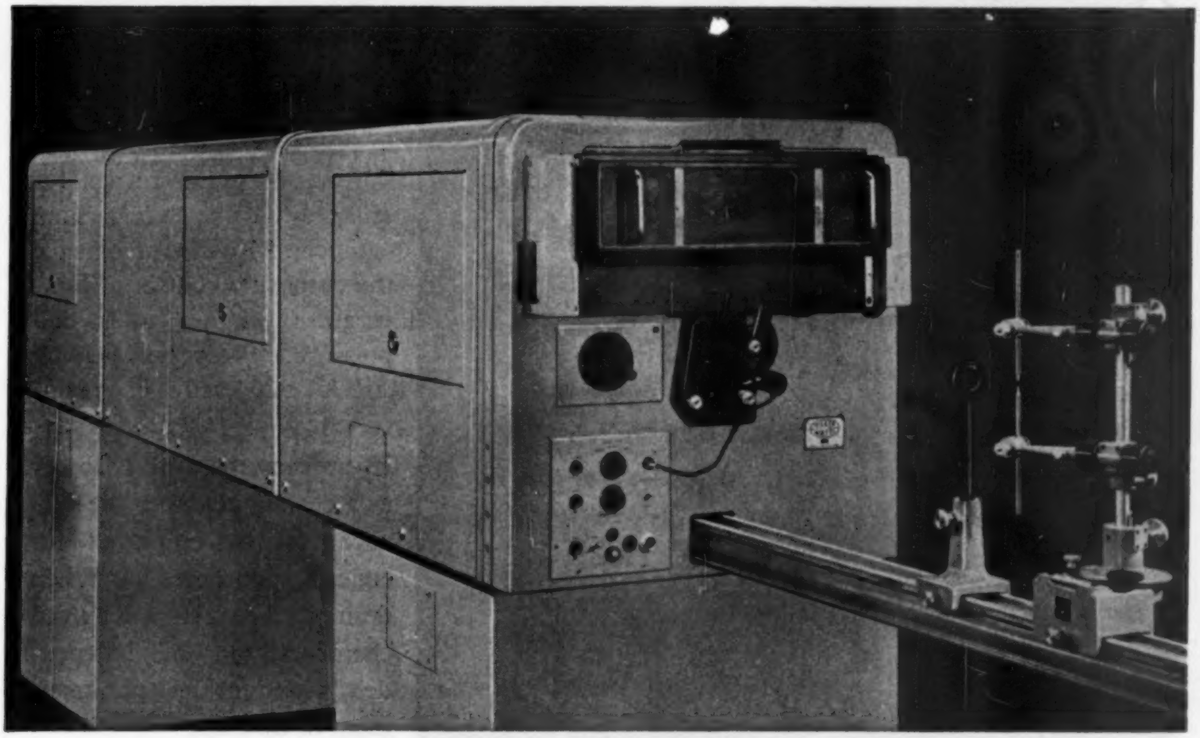
Of the lift-off type, the furnaces each have two charge bases, a slow cooling hood, automatic temperature control equipment and switchgear.

The furnace casings are fabricated from sheet steel formed into a cylindrical shell. To ensure rigidity during hoisting, heavy cross bracings are fitted into the roof of the bell. A lifting attachment is situated on the roof of the casing with a hook arranged for direct vertical lift from the shop crane.

Heating is provided by heavy nickel-chromium strip elements in sinuous form arranged around the wall of the chamber. Each base is fitted with a powerful electrically driven air circulating fan which sucks the air through the centre of the coils, blowing it upward around the outside and over the heating elements situated around the wall of the furnace. Uniform thermal conditions are essential in this process in order to obtain uniform metallurgical conditions throughout the strip, and forced convection ensures that these conditions are obtained and heating-up times are reduced. Each base is provided with pick-up contacts to mate up with those fitted onto the heating bell and are enclosed in sheet steel covers arranged to open and close automatically as the heating bell unit is raised and lowered.

The whole charge weight is taken on a cast heat-resisting steel-stool fixed into the hearth brickwork, the larger, more recent furnaces accommodating 3 coils weighing approximately 15 tons. Loading is carried out by a mechanical tongue fixture which is dropped around the coil by the overhead crane, and, on being raised, clamps the jaws around the coil giving a simple lift with the minimum of delay.

The rating of the earlier two heating bells is 220 kWs arranged in a single automatically controlled zone reducible to 110 kWs during the soaking period; that of the more recent furnace is 260 kWs, reducible during soaking to 130 kWs. Each furnace is designed for a maximum temperature of 950°C although the normal working temperature is approximately 800°C. When the soaking period is completed, the heating bell is lifted off and transferred to another base where another charge has been loaded. Thus continuous working of each furnace, in conjunction with its two bases, is assured.



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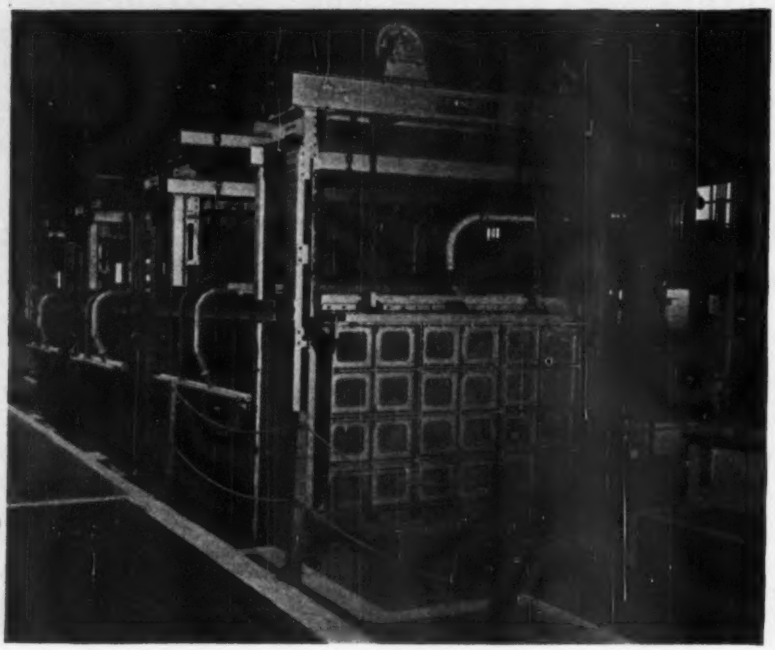

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The three separate chambers of this City Gas Fired Furnace are 12 ft. long by 10 ft. in effective width. They are each equipped with two electrically operated self-locking doors and operate as independent units.

The castings are preheated from cold to 300° C. in the first chamber and then pass to the second chamber where they are raised to 750° C. They are finally heated to 1,100° C. in the third chamber, and after soaking are quickly withdrawn by an extractor gear and conveyed to the oil or water tanks for quenching. The chambers are equipped with instruments for the automatic control of temperature, air/gas ratio and pressure. Prescribed heating curves can easily be maintained.

By utilising the third chamber as a cooling chamber the furnace can be employed for annealng purposes. When desired, the first and third chambers can be independently used for the batch treatment of castings.

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

March, 1960 Vol. LXI. No. 365

Nickel Outlook

DURING the immediate post-war years when steel was in very short supply, particularly the special grades, an executive of an engineering firm set out on a steel-finding tour to see whether personal contact would succeed where order forms, letters, etc. had failed. On his return he was asked whether he had obtained any steel, and had to admit failure, " But," he added, " I've drunk some of the best excuses I ever tasted." If all business were conducted on those lines, the alcohol bill for the nickel-producing industry since the end of the war would be staggering, for until the last two or three years the industry has not been in a position to meet the demands of the engineering and allied trades for nickel and nickel-containing alloys. During the period when the metal was in short supply, it was changing hands in the " black market " at around £3,000 a ton, when normal supplies were available in restricted quantity at £600 a ton.

To-day all that has changed, and supply exceeds demand to such an extent that Dr. John F. Thompson, chairman of the board of directors of The International Nickel Co. of Canada, Ltd., in a recent review of the nickel industry, said that despite the substantial rise in the 1959 consumption and the uncertainties in Cuba, free world supplies of nickel continue ample. After the war considerable efforts were made to develop materials that would facilitate economies in the use of nickel, and one wondered whether the discovery that nickel-free materials could be used satisfactorily for purposes for which nickel-containing steels and alloys had previously been thought essential would have repercussions when nickel became more freely available, particularly where the substitute material was cheaper. This may have happened to a limited extent, but not sufficiently so to have had any marked effect on nickel consumption.

Free world capacity for nickel production in 1959 was at the rate of about 550 million pounds, of which Canada accounted for over 70%, Cuba for 10%, United States for 4%, and New Caledonia, Japan and other sources for the remainder. This capacity is expected to increase by more than 100 million pounds in the next two years, and the 75 million pound contribution of International Nickel's new mining project at Thompson, Manitoba, takes on a new significance in the light of the current situation in Cuba. With a supply exceeding demand and a further increase in capacity on the way, the industry will no doubt continue to intensify its marketing activities and market research with a view to creating and increasing markets or recovering those lost to other materials. International Nickel's marketing, sales and research staffs have been realigned and augmented. Special groups have been created to promote the maximum use of established nickel alloys; a product development group has been formed to create, in conjunction with research staffs, new nickel-containing materials to satisfy the needs of new and potentially large markets; and a group of application engineers is devoting its attention specifically to the creation of immediate markets. The technical service activity to the trade has been enlarged and improved, and the sales forces have been augmented to cover all industries and industrial areas.

Such is the measure of the effort—in what fields is it likely to yield results? At an estimated 29% of free world consumption, stainless steel production uses more nickel than any other single application, and its use has expanded during the past year in the rocket and missile field. The architectural field is regarded as one of the great potential markets for stainless steel, and architects are becoming increasingly familiar with its properties and the variety of mill forms in which it is available. In the motor car, too, stainless steels have shown an advance economically as well as technologically for a larger amount of the trim. Early last year International Nickel—and in the United Kingdom its associate, The Mond Nickel Co., Ltd.—conducted a " Gleam of Stainless Steel " promotion designed to increase the use of nickel-containing stainless steel in household equipment, and the success which attended this effort has led to its extension in 1960.

High-nickel alloys account for 16% of consumption, and the transition from piston engines to jet and prop-jet power for commercial aircraft provides an expanding market for alloys capable of withstanding ever increasing service temperatures. Age-hardenable nickel-base alloys have recently been developed which permit the higher turbine blade temperatures necessary for greater efficiency of the engine. Gas turbine powered trucks and passenger cars are emerging from the prototype stages, and it may be that the most exciting possibilities for nickel in the gas turbine field will be found in the motor car industry. In the steam turbine, too, the trend has been towards higher and higher steam temperatures, and nickel-base alloys are under development for steam lines and critical regions of the turbines, whilst the high resistance to stress-corrosion cracking of alloys containing more than 40% nickel has led to more extended use of nickel-chromium and nickel-copper alloys in the nuclear energy field.

Having become so used to inferior chromium plating on motor cars, we had almost come to believe that our memories of pre-war plating were seen through rose-coloured spectacles, and that it never had been as good as we had believed. However, our original view was confirmed with the recent issue of details of the British Standards Institution scheme for ensuring plating quality suitable to the service requirements of the object plated. From this it must be evident, even to those whose knowledge of the subject is small, that one of the key factors is the thickness of nickel below the chromium deposit, and it is interesting to note that several U.S. automobile makers have increased the

thickness specification for nickel plate on bumpers and trim by as much as 75%. Transient interest in substitute materials has been diverted, and several 1960 models have returned to improved nickel-chromium plated grilles and other decorative components. Steady increases in the use of nickel plating have also been noted in the major domestic appliance fields. An important advance in the plating industry has been the development of "duplex" nickel plating, in which two successive layers of nickel are deposited, imparting marked improvement in corrosion resistance and quality of finish.

In the alloy steel field which, like electroplating, accounts for 15% of free world nickel consumption, new nickel steels have been developed for motor car gears which provide equal or better properties at lower costs than the steels previously used, whilst in heavy construction machinery, increasingly higher mechanical property requirements for certain parts have resulted in upgrading some presently used materials to higher nickel levels, as well as in replacing non-nickel-containing alloy steels. A new family of very high strength 25% nickel alloy steels has been developed and produced in the form of bar, plate, sheet and tubing, and their properties are expected to make them of particular interest for applications in aircraft and missiles, for high-strength wear-resisting precision bearings, for pressure vessels, and for many other industrial and defence uses. Other applications where the properties of nickel alloy steels are of advantage include low temperature equipment, where steels with 2¼–9% nickel are used, and large alternator rotor forgings, where there is a trend towards the use of steels with higher nickel content to improve strength and toughness.

In the foundry (12% of consumption) nickel is a most ubiquitous element, being alloyed with cast iron, steel, copper and aluminium, and being an essential ingredient of heat- and corrosion-resistant castings. Abrasion-resistant nickel-chromium cast irons have found widespread application, and the new nickel-containing austenitic ductile irons continue to be used in increasing quantities for manifolds and turbochargers on heavy duty diesel engines. Activity has been resumed to develop further the use of nickel in grey irons and ductile irons for engineering applications, and in the light alloy field studies of the advantages of nickel in improving the corrosion-resistance of aluminium in nuclear power fuel elements have continued, and investigations to improve the fabricating characteristics and properties of cast and wrought aluminium alloys have been initiated.

Copper nickel alloys continue to be used extensively in the power, petroleum and marine industries for heat exchanger applications, and account for 4% of the nickel consumption. Last year saw a doubling of consumption of these alloys as compared with 1958. Greater appreciation of the advantages of copper-nickel alloy castings from the standpoint of soundness and weldability is improving their commercial status. Other applications showing increased nickel consumption include the electronics field; the chemical industry, where, among other uses, it serves as a catalyst; the production of nickel-cadmium storage batteries; and finally, coinage. Nickel constitutes almost 10% of the annual metal consumption for coins, and in 1959, France, Greece and Uruguay decreed the adoption of pure nickel for higher denomination coins.

In concluding his review, Dr. Thompson said, "The effectiveness of renewed efforts to increase the consumption of nickel through augmented marketing and research activities is evidenced by the increased use of the metal during 1959. As far as International Nickel is concerned, these efforts will be continued with vigour, not only to assure markets for present supplies of nickel, but also for the largely increased supplies which will be forthcoming by 1961."

Meeting Diary

1st April

Institute of Fuel, South Wales Section. "The Benson Boiler". Four papers by staff of The Steel Company of Wales. South Wales Institute of Engineers, Park Place, Cardiff. 6 p.m.

5th April

Institute of Metals, Oxford Local Section. Annual General Meeting, followed by "Low Temperature Properties of Metals", by H. M. Rosenberg. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institute of Welding, Slough Section. "Shop Inspection of Welds". Lecture Hall, Community Centre, Farnham Road, Slough. 7.30 p.m.

6th April

Society of Chemical Industry, Corrosion Group. Spring Lecture. "The Presentation of Corrosion Information", by Dr. J. W. Jenkin. 14, Belgrave Square, London, S.W.1. 6 p.m.

7th April

Institute of Metals, London Local Section. Annual General Meeting followed by a Symposium on "Metallographic Techniques". 17, Belgrave Square, London, S.W.1. 6 p.m.

Leeds Metallurgical Society. "Metallurgical Research in the Department of Scientific and Industrial Research", by Dr. N. P. Allen. University Staff House, University Road, Leeds. 6.30 p.m.

Liverpool Metallurgical Society. "The Examination of Irradiated Fuel Elements", by Dr. G. B. Greenough, followed by 12th Annual Meeting. Library, Dept. of Metallurgy of the University of Liverpool, 146, Brownlow Hill, Liverpool, 3. 7 p.m.

8th April

West of Scotland Iron and Steel Institute. Annual General Meeting. Short Papers on "Mill Operation", by T. Harris, G. Steel and J. Craig. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

11th April

Institute of British Foundrymen, East Anglian Section. Annual General Meeting, followed by paper on "An Introduction to Patternmaking in Plastics", by H. G. C. King. Lecture Hall, Public Library, Ipswich. 7.30 p.m.

12th April

Powder Metallurgy Joint Group of the Iron and Steel Institute and the Institute of Metals. Symposium on "Continuous Processing in Powder Metallurgy". Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1. 10.30 a.m. to 5 p.m.

Institute of Welding. Open Meeting of the Technical Committee on Standardisation. 54, Princes Gate, London, S.W.7. Ticket only.

13th April

Institute of Welding, South London Branch. "Prospect for Welding" (Forum), followed by Annual General Meeting. 54, Princes Gate, London, S.W.7. 7.30 p.m.

14th April

East Midlands Metallurgical Society. Annual General Meeting, followed by "Reactor Metallurgy". School of Art, Green Lane, Derby. 7.30 p.m.

Institute of British Foundrymen, Beds. & Herts. Section. "Annual General Meeting, followed by film "Great Names", produced by F. H. Lloyd & Company, Ltd. K. & L. Steelfounders & Engineers, Ltd., Letchworth. 7.30 p.m.

21st April

Society of Chemical Industry, Corrosion Group. Annual General Meeting and "Electrode Processes in Primary Batteries," by D. H. Collins. 14, Belgrave Square, London, S.W.1. 6 p.m.

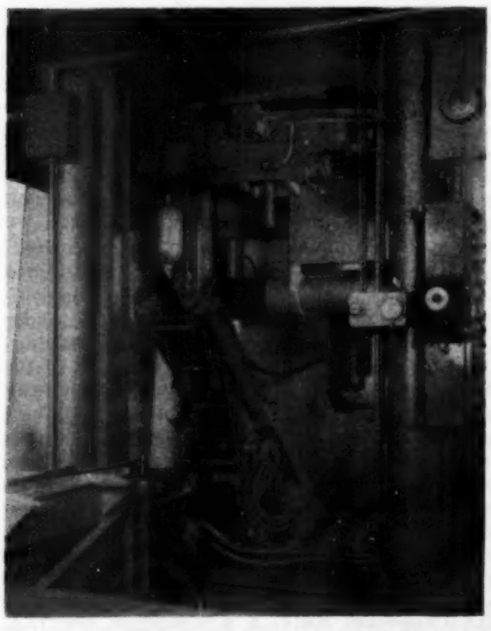
Continuous Casting Machine for Copper Billet and Slab Production

Overall view of the machine.

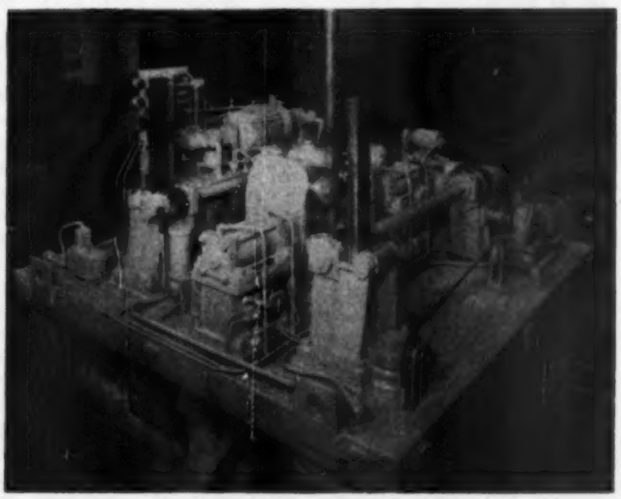
PROGRESS in copper billet and slab casting technique has resulted in the development, by Loma Machine Manufacturing Co., Inc., of New York, of what is claimed to be the world's most productive and versatile fully continuous casting machine. The equipment handles copper in all its various forms—from phosphorus de-oxidised and oxygen-free to fire-refined and tough-pitch types. The basic design of the machine also lends itself to the casting of brasses and bronzes, and aluminium and magnesium alloys. The shapes produced on the unit include round piercing and extrusion billets, square wire bars and rectangular slabs. The production capacity of the machine ranges from 3 tons/hr. for double-strand casting of 3 in. diameter billets to 10 tons/hr. for single-strand casting of $5\frac{1}{4}$ in. × 33 in. slabs.

The machine is usually fed with liquid metal from either an arc or induction melting furnace followed by an induction holding furnace. The molten copper at a temperature of 2,150° F. (1,175° C.) then flows through a special refractory-lined distributor equipped with down-spouts extending into the moulds. The rate of flow of the metal through the down-spouts extending below the metal surface is controlled by the operator with needle valves. This "underpouring" method assures a smooth, splash-free entry of clean metal into the mould cavity, thus eliminating internal porosity and inclusions in the cast material.

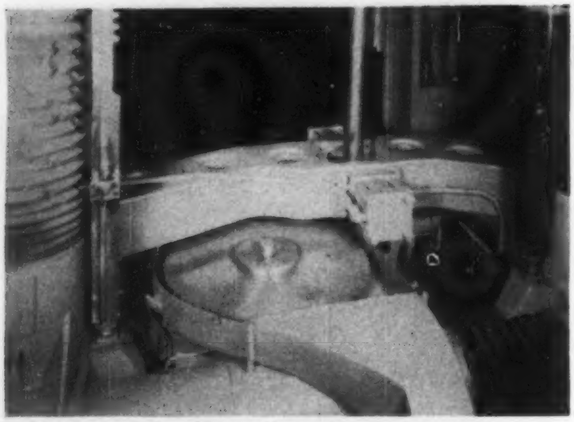
The billet, bar and slab moulds are of copper construction and are mounted at the top of the casting machine, and the mould water jackets feature a special internal baffle design which greatly enhances their heat removal capacity. The cooling water initially flows through the mould jackets and then emerges from an adjustable slot at the mould bottom to impinge on the solidified metal surface in direct spray form. The spray



Lower casting machine level, showing a cut billet being removed by the tilting discharge basket.



Upper casting machine level, showing the withdrawal of a solidified billet by the two pinch roll sets.



Close up view of flying saw cutting through a billet being gripped by the double clamps.

water is collected in a water box mounted below the moulds and is recirculated.

To prevent sticking of the cast copper to the mould and to ensure a smooth metal surface, the entire mould assembly is oscillated by a reciprocating gear. The vertical stroke is only a fraction of an inch, and the rate of vibration can be adjusted up to several hundred cycles per minute by means of a variable speed drive.

The solidified metal strands are continuously withdrawn from the moulds by a double set of 9 in. diameter pinch rolls made of stainless steel. Proper clamping pressure is applied to the pinch rolls by opposed hydraulic cylinders and, in addition, spring pressure is provided to hold the stock firmly in case of power failure. The pinch rolls are driven through reduction gearing by a 5 h.p. D.C. motor to obtain infinitely variable casting speeds up to 60 in./min.

Immediately below the withdrawing rolls and mounted on a travelling carriage is the flying circular cut-off saw. The vertical travel of the saw is along two of the four main columns of the machine, whilst its horizontal travel is along two horizontal columns on which the travelling carriage is guided. During cut-off, the descending castings are engaged by hydraulically-operated clamps situated on both sides of the sawblade. The saw employs a 36 in. diameter high speed steel segmental blade driven by a 40 h.p. motor at 1,200 ft./min. The cutting feed rate is adjustable up to 2 in./sec., whilst the return rate is 4 in./sec. The entire cycle of clamping, carriage descent, saw advance, saw return and carriage return is performed automatically.

The cut billets or slabs are received in the discharge basket, which is tilted automatically by a pneumatic cylinder through 90°. Once the basket reaches its horizontal position, the castings are ejected onto a roller conveyor by air cylinder action. Finally, an air-operated stamping device applies an identification mark to one end of each casting. The product is then removed to stockpile or immediate use.

The major advantages claimed for the new Loma continuous casting machine are :

(1) Machine mechanisation requiring only one operator improves plant productivity.

(2) Steady casting conditions give uniform, dense ingot structure from end to end.

(3) Smooth metal pouring eliminates turbulence and entrapped oxides, dross and gases.

(4) Rapid cooling produces a fine-grained sound structure, even in large cross-sections.

(5) Predominantly longitudinal solidification prevents piping and internal stresses.

(6) Long casting length and absence of cropping losses improve yield.

(7) Simple, short moulds reduce cost of and space required by casting shop inventory.

Wellman Subsidiary

Due to the expansion of furnace building and contracting activities, particularly in the field of oxygen steelmaking processes, the Wellman Smith Owen Engineering Corporation, Ltd., have decided to segregate and operate the sales organisation of the furnace building department as a separate subsidiary company—Wellman Smith Owen (Furnaces), Ltd., Parnell House, Wilton Road, London, S.W.1. The operations of this subsidiary company will be supported by the full engineering and manufacturing resources of the Wellman group for the design and construction of furnaces for the ferrous and non-ferrous industries, soaking pits, metal mixers, and installations involving the most recent oxygen steelmaking techniques.

The following executives of the parent company have been appointed directors of this subsidiary, by way of addition to the board under the chairmanship of Sir Peter G. Roberts, Bt., M.P. : Mr. G. Talbot, (Managing), Mr. C. D. Wattleworth, Mr. W. H. Day, Mr. C. Brooks, and Mr. D. A. Hume. The other additional board appointments which have been made within the Wellman group are : Mr. W. H. Day and Mr. V. Bellingham as directors of The Wellman Bibby Co., Ltd., and Mr. D. A. Hume as director of Robinson and Kershaw, Ltd.

New Foundry Plant Company

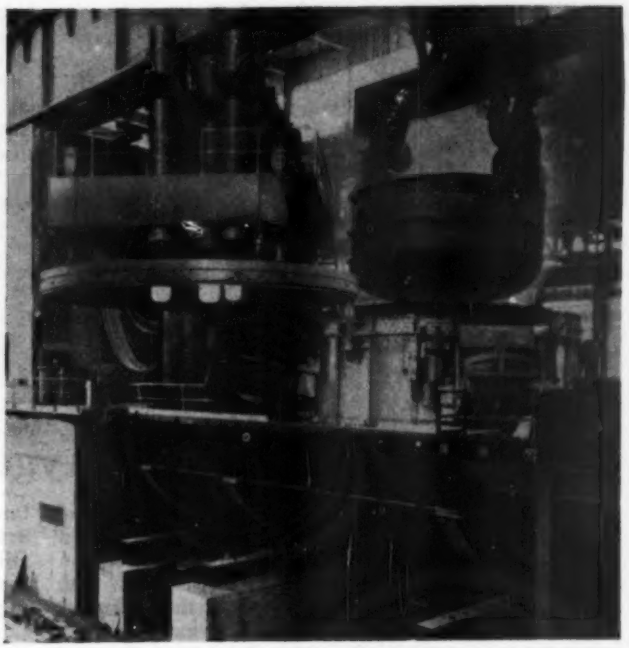
Efco, Ltd., and Stein & Atkinson, Ltd., announce that they have joined forces in a new company, namely, Foundry & Metallurgical Equipment Co., Ltd., with headquarters at Netherby, 161, Queens Road, Weybridge.

This company will design, manufacture and supply an extensive range of foundry equipment, including gas and oil fired crucible melting furnaces ; gas, electric and oil fired annealing furnaces and ovens specifically for foundry use ; batch and continuous core stoves ; core blowers ; mould and sand driers ; shell moulding and mould closing machines ; and gravity die casting equipment. In addition, they will manufacture and supply, under licence, the Efco-Diamond rotary reactor for desulphursing iron and steel by a new method developed in the U.S.A. by the Diamond Alkali Company. The company will also offer complete hot-blast cupola plants embodying air heaters of the well-known Escher type and with the latest water jacketed reaction zone. Arrangements have been completed with Sinex Engineering Co., Ltd., for the new company to offer Sinex vibratory equipment for knock-out grids, screens, feeders and conveyors for the foundry industry, and with Aldridge Industrial Oils of Cleveland, U.S.A., for the sale of die lubricants.

The directors of the new company are : Mr. D. F. Campbell (Chairman), Mr. C. J. S. Atkinson, Mr. J. A. Monks and Mr. C. H. Williams. The consulting metallurgist is Dr. A. G. Robiette.

Britain's Largest Electric Arc Steel Furnaces

G. W. B. Furnaces to Supply First Two 150 Ton Units for Templeborough Melting Shop



150 ton arc furnace with roof swung aside

FOLLOWING the recent statement of The United Steel Cos., Ltd., that they are to spend £10 million installing what will be the largest electric steel-making plant in the world at their Steel, Peech and Tozer branch, G.W.B. Furnaces, Ltd., of Dudley, have announced that they are to supply the first two giant electric arc furnaces for the project. These furnaces will be almost twice as large as any previously built in Great Britain, and the electrical demand will be equivalent to that of the town of Huddersfield, each furnace having an electrical rating of 40,000 kVA. The G.W.B. arc furnaces will be of Demag design although, apart from the regulator, the equivalent of which is unobtainable in this country, the units will be entirely of British manufacture, the steel construction being carried out by Distington Engineering Co., Ltd., a United Steel subsidiary.

Each furnace shell will have an internal diameter of 24 ft., a nominal capacity of 150 tons, and will be capable of melting at the rate of 1 ton/min. In practice the furnaces will be used for a maximum of 110 tons ingot weight. Construction of the furnaces will follow the well known Demag king pin or gantry design, in which the roof is the only item lifted from the shell when the top charging takes place. The weight of the electrode equipment is permanently carried by the gantry which, after raising the roof, swings aside around a king post ready for furnace charging. Roof raising is by hydraulic cylinder and the gantry is swung aside by an A.C. motor and gear train. Shell and gantry are mounted on a platform which is supported by three arc shaped rockers which allow the furnace to tilt forward 45° for pouring and 15° backwards for slagging. The drive for tilting will be by means of D.C. motors, through a gear train to pendant pin racks attached to the underside of the furnace.

To facilitate the initial melt, shell rotation is incorporated and will allow the drilling of the scrap in three positions of each electrode. Rotation is 40° either side the normal electrode position. This device is advisable when the scrap used is very light and the first downward movement of the electrodes provides insufficient pool of molten metal for protecting the lining. Alternatively, when heavy single items of scrap such as ladle skulls are included in the charge, or when non-metallic components or slag covered areas give poor electrical conductivity, it is convenient to rotate the shell and re-strike the arcs in a fresh position. Shell rotation is by means of an A.C. motor and gear train.

One of the serious shortcomings of the modern high powered arc furnace is the uneven lining wear due to the hot spot which appears around the centre electrode, and to a lesser extent one of the other two electrodes will also have a minor hot spot. This undesirable state of affairs is caused by the shorter length of busbar work to the centre phase and by the unequal mutual inductance between the phases causing the arc voltages to be unequal. These furnaces will embody a patented feature of De Roll, Switzerland, whereby the delta will be closed on the electrodes so that all busbar work from the transformers is compensated by the full interleaving of the flow and return bars.

While G.W.B. are in a position to offer hydraulic or static magnetic amplifier or rotating regulators for controlling the electrodes, the hydraulic system has been chosen in this instance because of its high speed of response. The regulator is a true impedance type and in principle is not unlike the ordinary moving coil loudspeaker. An aluminium former carrying the current and potential windings relative to the arc condition operates in a strong magnetic field provided by a D.C.

magnet, and moves in accordance with the variations in the values of the current and potential components. A servo oil control valve is connected to this former so that movement of the latter controls the flow of oil to the hydraulic valve regulating the electrode position. The windings being air cored have a high rate of response and the sensitivity is of a very high order. As the hydraulic control valve is subject to oil pressure at each end of its operating piston, it will come to rest when the two pressures are equal, and this arrangement eliminates any possible variation in calibration arising from variation in oil pressure or viscosity.

Single-acting ram-type cylinders are utilised for positioning the electrode equipment, and counter balance is provided by arranging the exhaust from the cylinders to be at a positive pressure. This counter balance pressure is variable and can be maintained quite accurately at the preset figure.

Power for the arcs will be provided by 3-phase transformers which will follow modern design tendencies. On-load tap changing will be provided in a regulating transformer which feeds into a fixed ratio stepdown transformer. Both transformers are contained in the same tank and are forced oil cooled through external water cooled heat exchangers. Two coolers each capable of dealing with the full load losses of the transformer are provided. The incoming supply will be 33,000 volts, 3 phase, 50 cycles, and the maximum arc voltage will be 565 volts.

The total output of the finished plant will be 1,350,000 ingot tons of steel a year, and the first G.W.B. furnace is expected to commence operation in 1963.

More Tonnage Oxygen for Steelworks

Recent expansion plans announced by the steel industry have placed an even greater emphasis on the importance of tonnage oxygen to steelworks in the U.K. Following negotiations and discussions with steelmakers, arrangements have been made by British Oxygen Gases, Ltd., to increase its tonnage oxygen supply investments in several steelmaking districts, and to erect further tonnage oxygen plants at new steelworks' sites. Additional plants, providing for the increased requirements of seven individual steelworks, will produce 1,500 tons of gaseous oxygen a day—more than doubling the present tonnage supply to the industry. The new installations will mark a further important stage in an established service offered by B.O.G., in making tonnage oxygen available to the steel industry.

At the present time, demands for oxygen in the manufacture and refining of steel frequently amount to several hundreds of tons a day by individual works. Such requirements can only be met satisfactorily by the local erection of tonnage plants designed to supply gaseous oxygen directly by pipeline to the consuming processes. As the international demand for steel has expanded, so the use of oxygen in metallurgy has grown. During the last ten years oxygen has become well established for electric furnace refining and the manufacture of low carbon steels in open hearth furnaces.

The highly successful Linz-Donawitz process is being developed rapidly, and soon there will be three basic converter plants in the U.K. producing steel refined with oxygen. By this new method, 1 ton of gaseous oxygen—about 25,000 cu.ft.—is required for every 10 tons of steel produced. Oxygen also has a significant role in established processes in permitting increased tonnages of steel to be produced at lower cost from existing plants. A modification of the open hearth process has been developed at the steelworks of the Appleby-Frodingham Steel Company, Scunthorpe (a branch of the United Steel Companies, Ltd.), which assists in competing more economically with other processes.

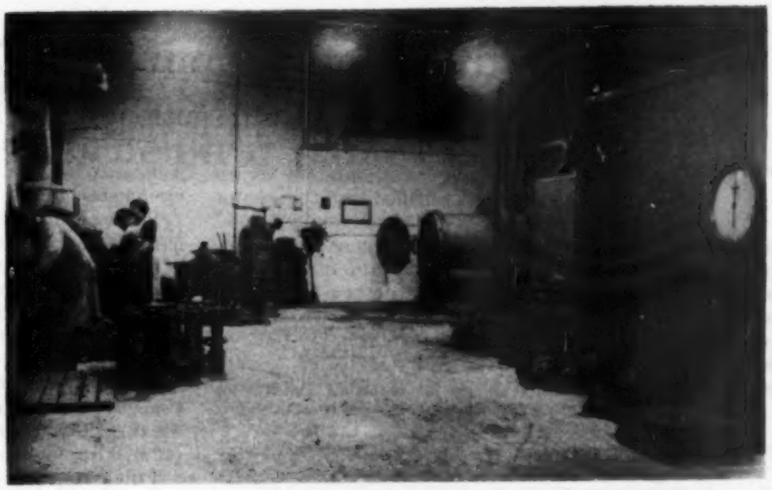
New and Augmented Supplies

The first tonnage oxygen plant in the U.K. was put into operation by B.O.G. in 1956 at its works at Margam, near Port Talbot. The nominal production capacity was 100 tons/day (100,000 cu. ft./hr.), and it supplied the adjacent works of the Steel Company of Wales. Another tonnage plant, installed later, increased gaseous oxygen available to this steelworks to 300 tons/day. Because of still further expansion, the Steel Company of Wales will soon have a supply of 500 tons/day from three tonnage oxygen systems at the Margam site. The Consett Iron Co., Ltd., in Durham, previously drawing its oxygen requirements from a 100 ton/day supply, is now to consume up to an additional 200 tons/day from two new installations, and the South Durham Steel and Iron Company is to make use of a new tonnage oxygen plant at West Hartlepool with a production capacity of 100 tons/day. At Scunthorpe, Lincs, an existing 200 ton/-day plant is to be augmented by a further installation of similar capacity. This is to satisfy the combined requirements of steelworks in the district, including Richard Thomas and Baldwins' Redbourn works and the Appleby-Frodingham Steel Company. At Middlesbrough a 200 ton/day system pipes supplies to several local steelmakers.

Two new tonnage plants having a total production capacity of 400 tons of oxygen a day, will supply the Spencer works at Newport, of Richard Thomas and Baldwins, Ltd., when the plant is commissioned in the autumn of 1961. Already, at its Ebbw Vale works, this company draws tonnage oxygen supplies from an established 100 ton/day system. Colvilles, Ltd., will have the oxygen requirements of the new steel sheet mill at Ravenscraig in Scotland met by a 200 ton/day plant at Motherwell, and a second plant of the same capacity will enable the application of oxygen to be further extended to Colville's melting shops at Dalzell and the Lanarkshire works.

Responsibility for the design, construction and erection of tonnage oxygen plants is vested in BritishOxygen Engineering, Ltd. The installations are then operated and maintained by B.O.G., whose technical knowledge and experience in the use of oxygen in steelmaking is placed at the disposal of the steel industry. Close cooperation between B.O.G. and the steelmakers—especially during the industry's current expansion programme—is of major importance in making available adequate supplies of oxygen at the lowest cost. In the face of keen competition for overseas steel markets, this continued service to the steel industry by B.O.G., will greatly assist further progress by the U.K. steel industry.

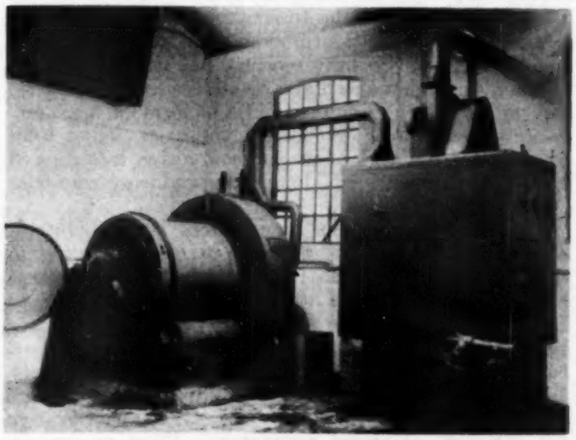
New Casting Dressing Shop for Pump Manufacturer



General view of the new dressing shop with, on the right, one wall of the shot blasting cabinet and, right background, the Centriblast rumbling barrel

NEW premises have recently been provided for dressing iron and non-ferrous castings at the works of Lee, Howl, & Co., Ltd., Tipton, Staffs., the old dressing shop having become outdated. The 60 × 30 ft. shop is situated adjacent to the iron foundry and houses new, as well as certain existing, plant and equipment. The shop is designed to handle 1,200 tons of castings a year, the weight of casting varying from a few ounces to three tons. Castings are for the various pump parts and accessories, and the variety of castings produced is illustrated by the pump range, which is from small hand pumps to machines requiring prime movers of 350 h.p.

One of the major items of new plant is a Spencer and Halstead shot blasting cabinet, measuring 15 × 10 × 8 ft. This plant is equipped with a magnetic separator under the floor, so that, if required, de-coring can take place in the cabinet. The larger size castings are brought from the iron foundry on a bogie mounted on rails terminating in the shot blasting cabinet. Heavy castings are also handled in the shop by a 3 ton overhead runway chain hoist. The shot blasting cabinet is fitted with a special glass roof and rubber lined walls, which reduce noise and plate wear, and Dallow and Lambert dust extraction equipment is installed.



The Centriblast rumbling barrel and dust extraction equipment

Next to the shot blasting cabinet is a new Centriblast (Spencer & Halstead, Ltd.) rumbling barrel for the smaller castings. The machine operates on an automatic cycle controlled by a time switch, and all that is required of the operator is to load and unload. The time cycle is four minutes, as against four or five hours by previous methods. This machine has had the effect of cleaning the smaller castings more efficiently than any other previous means and, of course, in a fraction of the time.

The Luke and Spencer grinders, being of a comparatively modern design, were transferred from the old shop to the new, and this equipment is adequately protected by dust extraction equipment made by Luke & Spencer, Ltd., and by Air Equipment Control, Ltd. (Dusguard). For the cutting-off of gates and runners on non-ferrous castings a new 14 in. abrasive wheel cut-off machine by F. E. Rowland & Co., Ltd., has been installed ; the cutting-off of gates and runners on large castings is done by an existing portable pneumatic cut-off machine equipped with an " elastic " wheel.

The benches, for hand-fettling, and other small equipment are situated on the opposite side of the shop to the shot blasting cabinet and rumbling barrel, and in fact, to a certain practical extent, there is an anti-clockwise flow of work round the outer perimeter of the shop, leaving the centre floor area free.

Heating in the shop is by Radiant steam heated panel radiators (Wellington Tube Co., Ltd.) ; lighting is by tungsten and mercury vapour bulbs and by natural light through windows which are glazed with Perspex to obviate glass breakage. The walls of the shop have been painted, instead of white-washed, to enable easy cleaning and washing down.

Resistivity of Aluminium Conductors

Recommended International Specification

THE world-wide importance of aluminium as an electrical conductor is confirmed by the recent issue by the International Electrotechnical Commission of "Recommended Specifications of Resistivity for Aluminium and Aluminium Alloy Conductor". There are four documents, produced over the last two years, and obtainable from the British Standards Institution or direct from the I.E.C., 1, Rue de Varembe, Geneve, Suisse. They are :—

No. 104 : "Recommendation for an international specification for aluminium alloy conductor wire of the aluminium-magnesium-silicon type."

No. 105 : "Recommendation for commercial-purity aluminium busbar material."

No. 111 : "Recommendation for the resistivity of commercial hard-drawn aluminium electrical conductor wire."

No. 114 : "Recommendation for heat-treated aluminium alloy busbar material of the aluminium-magnesium-silicon type."

The issue of these recommendations is expected greatly to facilitate the application of aluminium in various countries, as there is now an agreed level of quality of material for the various applications. In addition, the standards are a useful guide to national committees responsible for the preparation of their own national standards, and, of course, it will also facilitate to an almost incalculable degree, commercial dealings in products that incorporate aluminium conductors, e.g. overhead transmission lines.

The most important of these four standards at the present time is No. 111 : "Recommendation for the resistivity of commercial hard-drawn aluminium electrical conductor wire," which lays down a standard value and also a maximum value for hard-drawn aluminium wire as used in overhead lines, with or without steel reinforcement. The preface to this standard points out that international agreement on a standard value of resistivity has long been needed because of the world wide use of aluminium as an electrical conductor material : and the publication of the international standard of resistivity for copper (I.E.C. Publication No. 28, 1925) strengthened the view that a similar standard for aluminium would serve an equally useful purpose.

The standard value for the volume resistivity is fixed at 0·028264 ohm/sq. mm./m. at 20° C., and the I.E.C. document states that this is the value to be used for the purpose of calculating resistances of conductor wire. Thus, the issue of the document should avoid in future a diversity of practice in different countries that has led to considerable confusion and disagreement regarding the calculated resistance of overhead lines and other conductors made from this material.

Publication No. 111 also lays down a maximum resistivity for the wires which coincides with the standard value and can be used for acceptance tests on material in a conductor. Values are also given for density, constant mass temperature coefficient of resistance per °C., and coefficient of linear expansion per ° C. These constants are all required in calculating conductor resistances and conductor performance in various circumstances.

Publication 104 : "Recommendation for an international specification for aluminium alloy conductor wire of the aluminium-magnesium-silicon type," lays down the maximum resistivity (0·0328 ohm/sq. mm./m. at 20° C.) for this type of alloy wire that has long been in use for overhead conductors, with and without steel reinforcement. Naturally the addition of the alloying elements has increased resistivity to some extent, but at the same time has enabled great increase in strength to be achieved, so that the minimum laid down is 30 kg./sq. mm. (42,670 lb./sq. in.).

Publication 105 : "Recommendation for commercial-purity aluminium busbar material," specifies a resistivity of 0·0290 ohm/sq. mm./m. for pure aluminium busbars : the resistivity here is rather higher, in accordance with the practice of using aluminium of approximately 99·5% purity for busbar requirements : this is often adequate without recourse ot the use of electrical grade aluminium.

Publication 114 : "Recommendation for heat-treated aluminium alloy busbar material of the aluminium-magnesium-silicon type," lays down similar data for aluminium-magnesium-silicon alloy bar which has a maximum resistivity value 0·0325 ohm/sq. mm./m. at 20° C., a 0·2% proof stress not less than 17 kg./sq. mm. (24,175 lb./sq. in.), and a minimum tensile strength of 20 kg./sq. mm. (28,445 lb./sq. in.). This material is attractive to electrical engineers as it has similar mechanical properties to those of copper for busbars, and jointing with bolted connections is therefore simplified. One important purpose of this standard is to encourage as far as possible the use of only one type of material amongst the many of this type that can be readily produced but have higher or lower properties.

The need for agreed international standards of resistivity for aluminium materials used in electrical conductors has been felt for many years, and Committee TC/7 (Aluminium) of the International Electrotechnical Commission was constitituted in 1928 to consider the problem. However, only recently has it been possible to reach agreement acceptable to all interested countries, and to give this recognition in the form of an international standard. Some 30 countries have been interested in the work of the sub-committee, including of course all the principal aluminium-producing countries of the world.

The various electrical committees of the British Standards Institution that have been co-operating in the preparation of these I.E.C. recommendations have naturally correlated the values with those operative in British Standards, particularly as regards the resistivity value for hard-drawn aluminium wire used in overhead conductors, which are important export products. Indeed, a new step taken by Committee TC/7 is to initiate the preparation of an international specification for complete overhead conductors. Good progress is being made by the working group responsible for preparing the detailed draft.

The Effect of Composition and Structural Condition on the Resistance of 18-2 Chrome-Nickel Steels to Electrochemical Attack

By G. Newcombe

Admiralty Metallurgical Laboratory, Devonport Dockyard

The influence of chemical composition on the percentage delta-*ferrite present in the microstructure of* 18-2 *chrome-nickel steels is discussed and has been related to the factor of corrosion resistance. An investigation into the failure of two pump shafts, and additionally a series of immersion tests of selected steels coupled to a copper-base alloy in seawater, have produced information on the mechanism of breakdown and indicate a superior resistance to attack when a wholly martensitic structure is achieved.*

THE types of stainless steel available for use in industry can be divided broadly into three main groups: the "hardenable" group, which includes those steels capable of responding to heat treatment in the same way that plain carbon steels can be hardened and tempered; the "ferritic" group—high chromium irons having low carbon contents—which are not capable of useful response to heat treatment; and the "austenitic" group, which are similar to the former in their lack of response to heat treatment, but differ from the "hardenable" and "ferritic" groups by being non-magnetic. The work detailed in this paper is concerned with steels of the "hardenable" group, which meets a high proportion of engineering demands for a heat treatable corrosion resisting steel.

The author has recently been concerned with an investigation into the cause of deterioration suffered by two pump shafts which were directly connected with a bronze impeller and were operating in a seawater environment. The results of a chemical analysis performed on the shaft material (see Table I) showed the components to have been manufactured from a stainless steel whose composition classified it as 18-2 chrome-nickel steel to specification B.S. 970 En 57.

As previously stated, the shafts had in service been directly connected to a bronze impeller, and, since copper and its alloys are cathodic to stainless steels in the active state, it seemed evident that the deterioration sustained could reasonably be attributed to breakdown of the passive film and consequent galvanic action.

The steels embodied in the "hardenable" group are known to be susceptible to this form of attack, particularly the 12–14% chromium class, although a far greater degree of immunity has been claimed for the higher chromium content (15·5–20%), 2% nickel variety of steel. The late J. G. Monypenny said of these steels: "the 18–2 type of hardenable steel is generally the most suitable on account of its greater resistance—as compared with 12–14% chromium steels—against electrochemical attack resulting from contact with copper, although 18–2 steels are not completely immune from this form of attack when corrosive conditions are severe. If the passive film on the steel remains intact, contact with copper or its alloys will not lead to attack."

The subsequent metallurgical examination of these shafts has revealed a mechanism of attack connected with

TABLE I.—CHEMICAL COMPOSITION OF FAILED PUMP SHAFT

	C%	Si%	Mn%	P%	S%	Ni%	Cr%	Mo%
Failed Shaft ..	0·12	0·46	0·60	0·03	0·016	1·76	16·34	—
En.57	0·25 max.	0·1–1·0	1·00 max.	0·05 max.	0·05 max.	1·00–3·00	15·5–20·0	—

the presence of *delta*-ferrite in the microstructure, which may reasonably explain variations in the resistance of 18–2 steels to this form of attack, and the tests described in the ensuing chapters were undertaken to produce additional data.

Hardenable Chrome-Nickel Stainless Steels

Alloys of Iron and Chromium

In alloys of chromium and iron, a continuous series of solid solutions of *alpha*-iron and chromium is formed on solidification. Chromium has only a limited solubility in *gamma*-iron, and at the higher chromium contents *gamma*-iron is not formed at any temperature in the carbonless iron-chromium alloys. In relation to the application of thermal treatment to steel, the existence of this *gamma*-phase is of the utmost significance, the hardening by quenching of steels from high temperatures being achieved by carbon dissolving readily in iron in the *gamma*-form but being practically insoluble in the *alpha*-state. If, in the presence of alloying elements such as chromium, *gamma*-iron ceases to be formed, the thermal treatment of the steel becomes impossible. There are, however, alloying elements such as nickel that increase the stability and range of existence of *gamma*-iron and have a lowering effect on the range of the *alpha-gamma* change. At a chromium content of approximately 14%, a noticeable effect on the ability of the material to respond to quenching is observed, a higher temperature being necessary to achieve hardening of a steel, as would be expected from the general effect of chromium in raising the temperature of Ac_1 and in retarding the solution of carbide. The capacity of the material to harden diminishes very rapidly, so that with a sufficiently high chromium content the increase in hardness obtainable is very small, even with quite high percentages of carbon present.

Effect of Nickel and Carbon

The addition of nickel to iron has in many ways the opposite effect on structural changes to that of chromium.

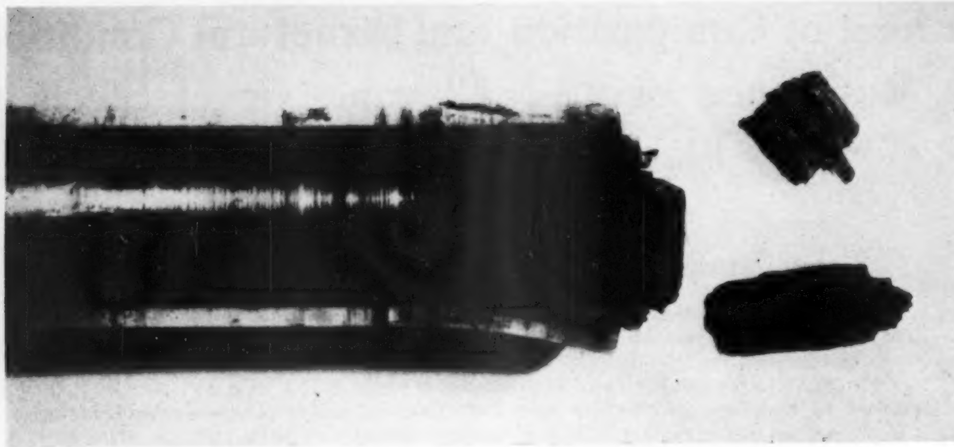


Fig. 1.—Deterioration sustained by the first shaft failure. (Note striation effect on fractured surfaces.) ×1

It stabilises the *gamma*-form of iron and widens the range at which it is stable. Both elements are similar, however, in retarding the rate at which structural changes occur during cooling. Nickel has the effect of increasing the formation of austenite at 950°–1,000° C. and consequently the hardening capacity, a fact which is demonstrated by comparing the hardening achieved by quenching nickel and nickel-free steels of the same carbon content. Elimination of *gamma*-iron is also delayed by the carbon content, amounts of austenite formed in Fe-C-Cr alloys containing more than 12% chromium depending on the carbon content. Moderate percentages of chromium and nickel added independently to plain carbon steels increase their hardening capacity, and when present together have a reinforcing action one on the other.

The effect of nickel in forming and stabilising the *gamma*-phase is much more obvious in the 17–20% chromium range than in the 12–14% chromium range. The 2% nickel added to the B.S. 970 En.57 steel has the effect of increasing the formation of austenite at 950°–1,000° C., as shown by the higher hardness values obtained from quenched steels of this composition when compared with nickel-free steels of similar carbon and chromium content, and by the decrease in the ferrite phase present in structures of quenched 17% Cr–0·1% C steels with the addition of 2% nickel.

Corrosion Resistance (General)

Chromium is undoubtedly the most important alloying addition made to steels in respect of increasing their resistance to atmospheric attack, and it can be said that the higher its content, other things being equal, the greater will be the resistance of the alloy to corrosion. Chromium can be present either in combination with the carbon in the form of carbides, or as a solid solution with the iron, and its beneficial effect on corrosion resistance is only fully realised when it exists in solid solution : the formation of carbides, although not enhancing corrosion resistance, is often reflected in an increase in mechanical properties. If, therefore, carbon contents are allowed to rise beyond a certain limit, the beneficial effect of a large percentage of chromium with respect to corrosion resistance will be nullified. The importance of the chromium and carbon contents in relation to the required mechanical properties is particularly apparent in the hardenable group of steels under discussion, where there must be a certain minimum amount of carbon present in order to achieve a desired hardness or tensile strength. In properly hardened 12–14% chromium steels, practically all the carbon—providing the content is not greater than 3%—will be in solution, and hence a maximum resistance to corrosion is achieved. As the carbon content is raised beyond 3%, chromium carbide will appear in the structure and the steel's resistance to corrosion will decline. Likewise the tempering of hardened 12–14% chromium steels at temperatures higher than 475° C. has the effect of precipitating chromium carbide. A similar effect is achieved in the higher chromium hardenable steels (16–20% chromium), the effects on corrosion resistance, however, being less noticeable in this class of steel because of the lower percentage of carbon (0·25% max.) present and the higher chromium percentage remaining in solution.

The addition of small amounts of nickel found in the class of steel under discussion has no appreciable influence on the resistance to corrosion, the main role of this addition being to give a greater hardening capacity. It does, however, have a profound influence on the character of the microstructure likely to be achieved, particularly with regard to the percentage *delta*-ferrite present, and in this connection the influence of nickel on corrosion resistance will be reconsidered later.

Investigation of Shaft Failures

Visual Observations

The result of the severe attack sustained by the first pump shaft is illustrated in Fig. 1, and it will be seen from the illustration that externally the original surface contour had been retained, and that the attack had developed in such a manner as to cause a splitting of the main body of the component into several sections, each one revealing a striation effect on the fractured surfaces. The threaded portion of the shaft which screwed into the bronze impeller had entirely disintegrated. An earlier stage in the development of the attack was discovered on examination of a second shaft working in the same environmental condition, and Fig. 2 amply demonstrates the lack of evidence of attack revealed by the surface

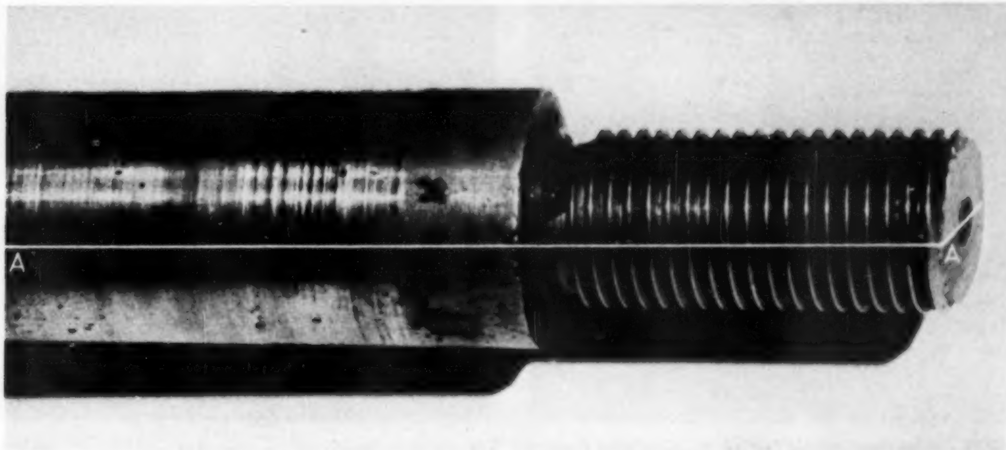


Fig. 2.—Surface condition of second shaft examined. ×1

condition of the component, although proof of the depth to which attack had already developed is given by the macrosection, taken from this shaft in a longitudinal direction along the line AA (see Fig. 3).

Microstructural Observations

Microsections from the affected areas of both components revealed a similar duplex martensite + ferrite microstructure, and one in keeping with the chemical analysis of the material as presented in Table I. This serves to demonstrate further a point previously discussed, namely that complete solution of the ferrite phase at high temperatures may or may not be achieved, depending on the percentage of nickel and/or carbon present in this class of steel, other things being equal.

Further survey of these microsections revealed the deterioration to have developed by preferential attack along the network of *delta*-ferrite at an associated carbide phase. Since, by virtue of reduction processes, this phase was present in an elongated and continuous network throughout the mass, it is not difficult to see why the deterioration had developed in such an insidious manner. It seemed logical to suppose therefore that breakdown of the passive film had occurred, with resultant galvanic action stimulated by connection with the bronze impeller. If complete absorption of the ferrite and associated carbide phase were effected, this form of attack could well be stifled and thus an increased resistance to the deterioration developed. Conversely, if large percentages of ferrite remained unabsorbed, serious and rapid attack under these conditions could be expected. To investigate these facts further and to obtain additional information on the *delta*-ferrite percentages likely to be met in this class of steel, a number of B.S. 970 En.57 steels were obtained and included in the following series of experiments.

Experimental Work

Analytical and Structural Features of 18–2 *Steels used in Tests.*

Six En.57 steels of varying cross-sectional thickness were withdrawn at random from working stocks of this material and subjected to both chemical analysis and microstructural survey. The results obtained from these analyses are presented in Table II, together with the requirements of B.S. 970 En.57.

It will be observed from these results that quite wide differences in composition are present in these steels, although it should be noted that all are within the compositional limits required by B.S. 970 En.57. Of the alloying additions present likely to influence the final structure of the material, the percentage differences of the two extremes (steels *B* and *F*) were carbon $=0\cdot105\%$, nickel $=0\cdot68\%$, and chromium $=0\cdot10\%$. In no instance

Fig. 3.—Macrosection of shaft illustrated in Fig. 2 taken along line AA and showing extent of attack. ×1¼ approx.

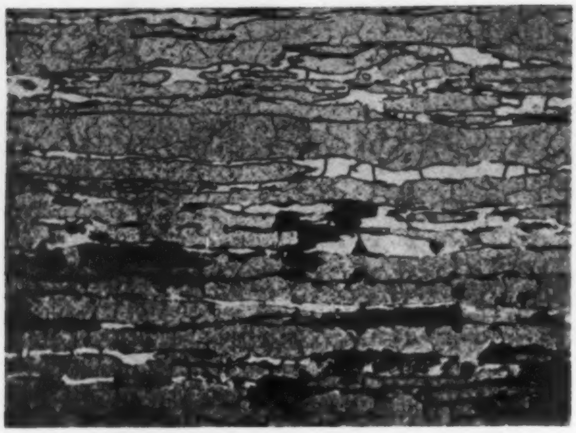


Fig. 4.—Preferential attack along the delta-ferrite phase Etched Stead's reagent. ×100

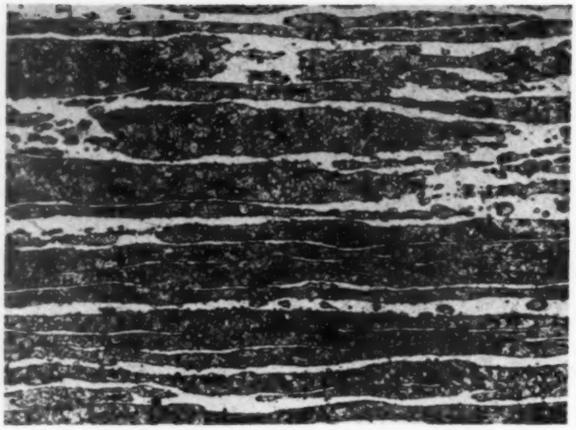


Fig. 5.—Microstructure of material F (carbon 0·10%, nickel 1·58%) showing high percentage of delta-ferrite. Etched Stead's reagent. ×100

were the maximum permissible figures for carbon, nickel and chromium approached.

Likewise, microscopical examination of the materials revealed wide structural differences with regard to the amount of *delta*-ferrite present, these differences being directly associated with high and low carbon and nickel contents. The variations in microstructure are shown in Figs. 5–8. According to observations made in connection with the investigation of the corroded shaft, material *F*, if subjected to galvanic action, should deteriorate extremely rapidly along the *delta*-ferrite phase. Two further materials were selected for inclusion in the tests, these being material *B*—for the obvious reason that a wholly martensitic structure had been achieved by the comparatively high carbon and nickel percentages present—and material *E*—by virtue of the somewhat different pattern and distribution of the ferrite, so different from the elongated form observed in other specimens.

Heat Treatment of Materials for Test

All materials to be used in the experiments were subjected to identical thermal treatment, this being in accordance with the requirements of B.S. 970 En.57 which recommends oil hardening from a temperature of 950°–1,020° C. and tempering at a suitable temperature between 550° and 650° C., the actual temperatures used being 1,000° C. and 600° C. for hardening and tempering, respectively.

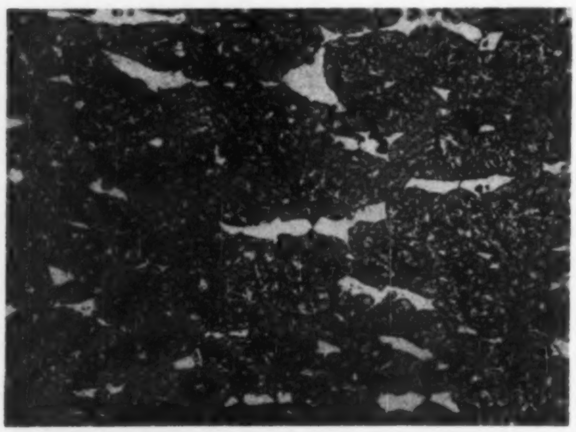


Fig. 6.—Microstructure of material E (carbon 0·145%, nickel, 1·870%) showing decrease in delta-ferrite and change from elongated pattern. Etched Stead's reagent. ×100

Microstructural examination of each specimen after this treatment revealed no significant change in structural conditions, and confirms that the chemical composition of samples *F*, *C* and *E* is such that further absorption of the *delta*-ferrite present in each of these materials cannot be accomplished by heat treatment. In fact, the stable banded *delta*-ferrite phase cannot be removed by any metallurgical process, and the material can only be produced without ferrite by the proper control of chemical composition during melting, and aiming for the high side of the allowable range of both carbon and nickel to open the *gamma* loop.

Formed by chemical segregation during solidification of the ingot, ferrite never transforms during subsequent hot work or heat treatment. In a recent paper published by Angstadt[2] in America on a hardenable quality of stainless steel similar to that concerned in these tests, the large percentages of *delta*-ferrite he found in the steels was attributed to close control on nickel and to the fact that the melters aimed towards the low side of the allowable range for this element in an attempt to conserve nickel when the steels were introduced from Great Britain to U.S.A. during World War II.

Test Procedure

Procedure I.—Specimens, cylindrical in shape and of similar dimension to the failed shafts, were machined

TABLE II.—CHEMICAL COMPOSITION OF EN.57 STEELS USED IN TESTS

Sample	Composition (%)							
	C	Si	Mn	P	S	Ni	Cr	Mo
A	0·115	0·52	0·64	0·026	0·027	1·87	16·41	0·10
B	0·205	0·60	0·73	0·027	0·040	2·26	16·64	0·22
C	0·155	0·52	0·56	0·025	0·054	2·23	17·11	0·12
D	0·16	0·34	0·59	0·023	0·040	2·27	15·63	0·13
E	0·145	0·40	0·59	0·034	0·029	1·87	16·17	0·17
F	0·10	0·16	0·46	0·019	0·045	1·58	16·54	0·08
En.57	0·25 max.	0·10–1·00	1·00 max.	0·05 max.	0·06 max.	1·0–3·0	15·5–20·0	—

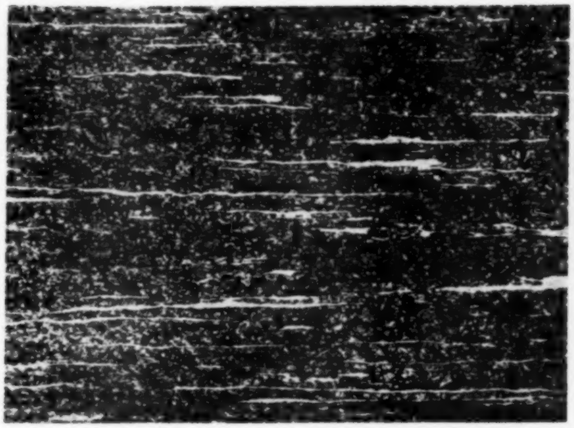


Fig. 7.—Microstructure of material C (carbon 0·155%, nickel 2·23%) showing marked decrease in delta-ferrite percentage. Etched Stead's reagent. ×100

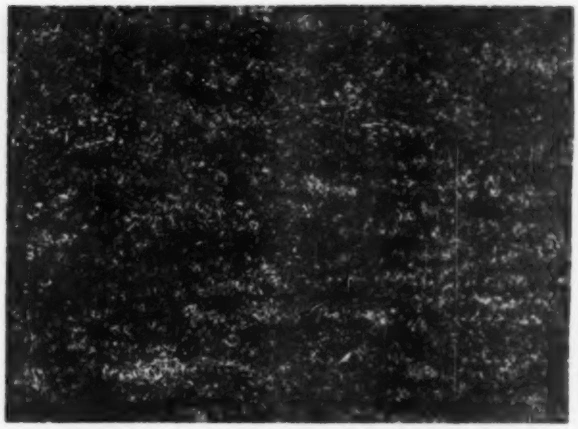


Fig. 8.—Wholly martensitic structure of material B (carbon 0·205%, nickel 2·26%). Etched Stead's reagent. ×100

from the bar stock selected as suitable in respect of compositional and microstructural features. The specimens were threaded for a length of ½ in. at one end, this being securely screwed into a block of gunmetal (nominal composition 86 : 7 : 5 : 2) the whole being immersed in seawater for a period of one month.

Procedure II.—A further series of tests was carried out to include materials *B* and *F*, these being designed to eliminate crevice conditions present in the previous tests. The specimens, smaller in dimension, were connected to bronze by an external circuit, the coupling wire being used to suspend the specimens but remaining out of contact with the seawater. The time of immersion (4 weeks) was reduced to a minimum in order to gain information on the initial pattern of the attack. At the end of the testing period all specimens were visually examined, sectioned in a longitudinal direction, and microscopically examined.

Specimen F (0·10%, C, 1·58% Ni) *Procedure I*

The external surface of the specimen when washed free of corrosion products revealed no visible deterioration of the underlying metal. Microscopical examination, however, revealed an area of attack to have developed adjacent to the bronze, and showed itself in the form of small centres of attack located at the boundaries of the *delta*-ferrite, the nature and distribution of these centres being illustrated in Fig. 9. It seemed very evident from higher power examination that the attack was concerned with the carbide phase surrounding the *delta*-ferrite boundaries in either spheroidal or layer form, its sphere of influence including both martensite and ferrite.

The attack initiated upon material *F* by test procedure II involved the definite removal of metal from the surface of the test specimen, producing areas of penetration characterised by a similar striation effect to that observed in the failed pump shaft, the attack being located at or just below the water line.

Specimen E (0·14% C, 1·87% Ni) *Procedure I*

As previously stated this material was chosen for inclusion in the tests by virtue of the different pattern and distribution of the *delta*-ferrite, so different from the elongated form. This particular pattern was a feature of the larger diameter bars examined (3–4½ in. diameter). Again attack was evident from the presence of corrosion

Fig. 9.—Centres of deterioration located at delta-ferrite boundaries: material F/leaded-bronze couple; test condition I. ×100

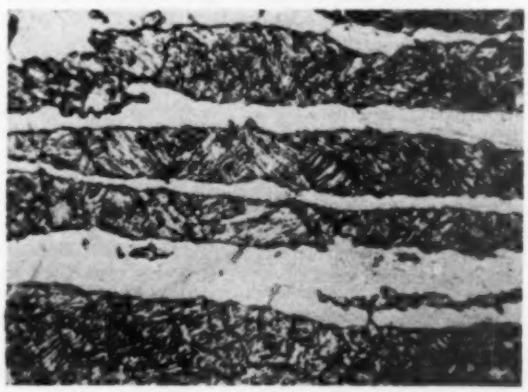


Fig. 10.— Carbide form present at ferrite boundaries ×500

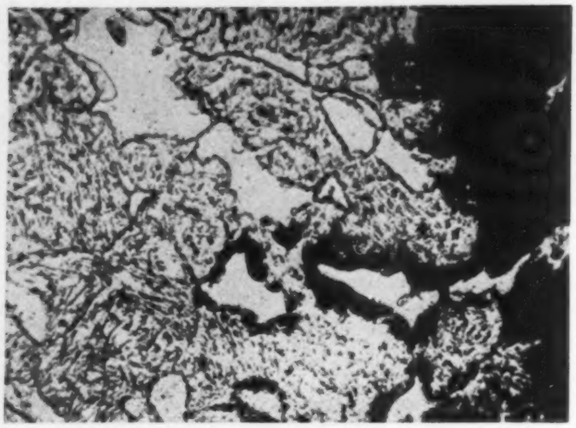


Fig. 11.—Isolation of the ferrite phase by preferential attack of boundary carbide. ×300

products on the specimen adjacent to the bronze. Microscopical examination showed a definite preferential attack of the carbide phase at the *delta*-ferrite boundaries, as shown in Fig. 11, producing a different pattern of deterioration, this being readily related to the change in ferrite distribution.

Specimen B, (0·205% C, 2·26% Ni) *Procedures I and II*

Microscopical examination supported visual observations made during these tests, and the absence of attack was confirmed at the cessation of the experiments.

It would appear from a survey of the results obtained that, under the conditions of test, in the 18–2 variety of hardenable stainless steel where duplex martensite + ferrite microstructures are present, breakdown of the passive film is more readily achieved in the area of the *delta*-ferrite boundaries than in the martensite. Such areas are thus made active and anodic to gunmetal and the attack upon them is accelerated by galvanic action, thus causing isolation and deterioration of the ferrite phase, with final disintegration of the martensite at an advanced stage of the attack.

Conclusions

(1) Within the scope of the compositional limits stipulated by specification B.S. 970 En.57 governing 18–2 chrome-nickel high tensile rust resisting steel, it is possible to achieve variations in the percentages of carbon and nickel which can in turn profoundly influence the percentage of *delta*-ferrite present in the microstructure of these materials. In an analytical and microstructural survey of six steels in this category, selected at random, a wide dissimilarity in composition and structure was revealed. Ordinarily the variations would not seem to be detrimental with regard to the resistance to general corrosive environments, but consideration in relation to the present work suggests that they have a greater significance when the steels are in the active state and in contact with cathodic materials in a corrosive environment.

(2) The steels are readily heat treatable, and the application of thermal treatment within the requirements of the specification will achieve the desired object of increased tensile strength, but if the balance of composition is such that the presence of *delta*-ferrite can be expected, thermal treatment will not be effective in reducing or eliminating its presence. It has been shown by correlation of composition and structure that steels of higher carbon (0·20–0·25%) and nickel (2·0–3·0%) contents exhibit a homogeneous martensitic structure in the fully treated condition.

(3) Limited experimental immersion tests which included certain of the steels have indicated that a greater degree of resistance to breakdown of the passive film can be expected from a wholly martensitic structure than from a structure containing a large percentage of ferrite. It can be stated that an increase in percentage ferrite will result in a corresponding decrease in resistance to this form of attack.

(4) This feature of structure, composition and corrosion resistance would seem to be of importance both industrially and in corrosion research work, since in terms of the six steels selected for test only two would have performed in a similar manner when coupled in the ways described. It can be similarly deduced that components such as the pump shafts investigated will perform in an unpredictable manner under the conditions described, depending on factors beyond user control.

(5) The question of the influence of *delta*-ferrite on the mechanical properties of these steels has not been investigated, but its presence has been connected with weakness under transverse loads, and its elimination with machining difficulties in the fully hardened condition.

(6) Finally, it is emphasised that this work has of necessity been limited in character, designed to follow up a situation revealed by a service failure and to place on record the findings of short term tests carried out on this class of stainless steel. This fact of varying resistance is confined to the conditions described, and no reflection is made on the material's general resistance to corrosion. It is hoped that these findings may be of interest to those concerned in the use of B.S. 970 En.57.

Acknowledgments

This work was conducted at the Admiralty Metallurgical Laboratory, Devonport Dockyard. It is published by permission of the Admiralty, but the views expressed are personal to the author. The author is indebted to Dr. C. D. Lawrence, Mr. J. N. Bradley and Mr. R. W. Robinson for their helpful advice and encouragement and the provision of facilities to enable the work to be undertaken.

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1 Monypenny, J. H. G., "Stainless Iron and Steel" Vol. I.
2 Angstadt, C. C., *Metal Progress*, June 1959, **75**, (6).

Firth Cleveland Steel Strip, Ltd., of Tipton, a member of the Firth Cleveland Group, now specialises in the production of high carbon steel strip to the exclusion of all other cold rolled products. The change-over resulted from the overwhelming and growing demand for this material from a large number of industries and from the success which the company is achieving in this field. Modern equipment enables the company to offer an extensive range of sizes which includes widths from ⅛ in. to 12 in. and thicknesses from 0·004 in. to 0·092 in., in coils or cut lengths. All steel is produced to fine limits, as, for instance, in the supply of strip for the textile industry where the tolerance limits are reduced to half those of the British Standards range.

A Preliminary Study of the Relationship between Tin Coating Grain Size of Electrotinplate and Flow-Brightening Conditions

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Following a brief description of a new laboratory electrotinplate flow-brightening unit, the author discusses the results of exploratory work performed on it. It is shown that the grain size of electrolytic tinplate may be influenced by a number of factors, which include strip temperature, strip speed, quench temperature, and circulation in the quenching tank. The tin coating thickness and the original smoothness of the steel base also have a limited influence. It is suggested that the phenomenon of "striping" produced by the use of high pressure water jets in the quench tank might be used to differentiate between the two sides of differentially coated tinplate.

LABORATORY facilities for the manufacture, under closely controlled conditions, of test-pieces of electrolytic tinplate have been in existence at the Tin Research Institute for some years and have been described in an earlier paper.[1] The circulating electrolyte plating cell remains unaltered at present, but the unit for flow-brightening the plated samples has been completely redesigned and built afresh. The new apparatus is more versatile and allows much closer control over the flow-brightening operations. This paper describes the equipment and some experiments concerning tin coating grain size carried out with it.

Description of Apparatus

A general view of the flow-brightening unit is shown in Fig. 1. The steel blanks, normally about 0·010 in. thick (90 lb. substance), are tinplated in the circulating electrolyte cell, and are then cut to 10·5 × 3·5 in. They are inserted in slots in the two solid copper conductor blocks of the specimen holder, details of which may be seen in Fig. 2, and contact strips are inserted between the ends of the sample and the thumbscrews to ensure a minimum contact resistance. The copper blocks are connected by long flexible leads, suitably looped to allow freedom for the specimen holder to fall, to a heavy-duty step-down transformer. The conductor blocks also have extension pieces attached to them carrying two grooved bakelite wheels on each side, running on vertical rails, while a strip of Perspex bolted to the extension arms above the specimen maintains rigidity of the holder. This design was employed after it had been found that any struts too close to the test-piece caused severe turbulence during high-speed quenching, which gave very non-uniform tin coating grain size.

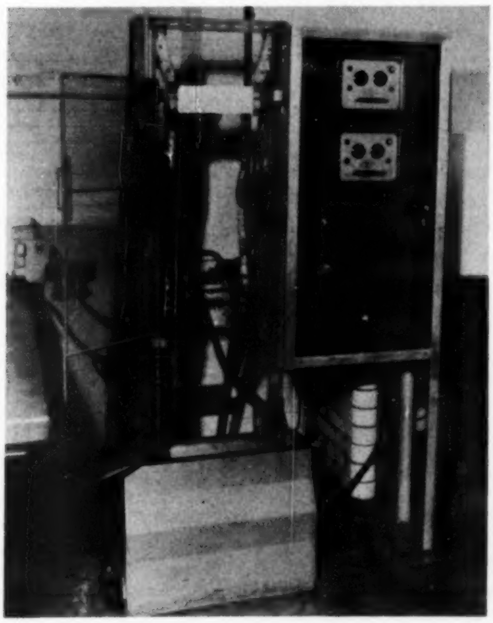


Fig. 1.—General view of laboratory electrotinplate flow-brightening unit.

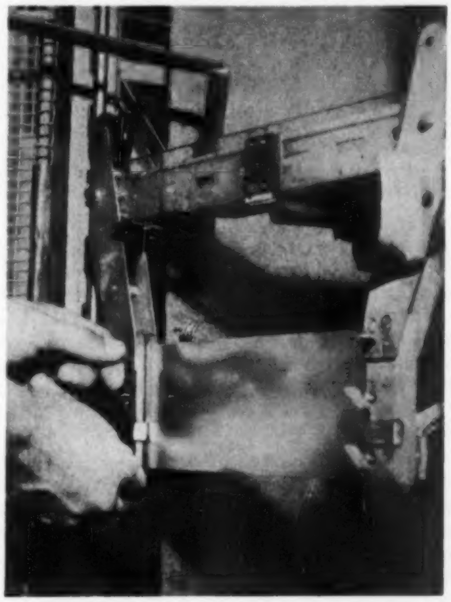


Fig. 2.—Detailed view of specimen holding jig.

The vertical rails, consisting of ¼ in. diameter rods,

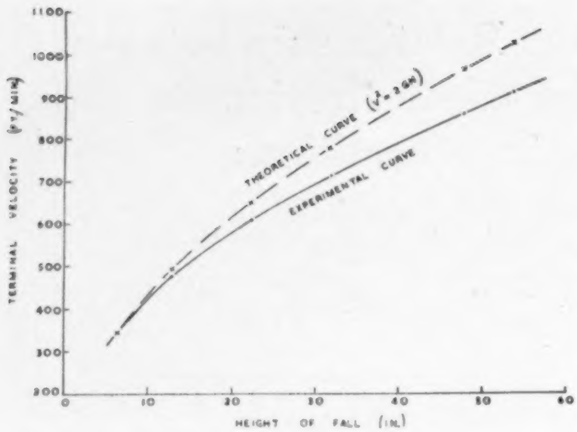


Fig. 3.—Curves relating height of fall and terminal velocity at water quench tank.

between which the specimen holder runs, are attached to the main framework of slotted steel angle. The height of the rails and framework is presently about 6 ft., in order that the descending test-piece can attain a maximum terminal velocity under gravitational acceleration of about 1,000 ft./min.

The test-piece is held above the quench tank by a pin, which is connected to a solenoid armature, projecting under the Perspex bar of the specimen holder (Fig. 2). The mating surfaces on the pin and the bar are made of polytetrafluorethylene to reduce friction and ensure instantaneous release of the sample when the solenoid is energised. This release mechanism may be positioned at the required height by choosing a suitable pair of slots in the framework, in order to obtain the desired quenching speed.

The terminal velocity of the leading edge of specimens entering the water quench for various heights of fall was measured by the simple method of making sine-wave traces on samples coated with lamp black, using a tuning fork of suitable frequency. Fig. 3 shows the theoretical and experimental curves relating velocity in feet per minute with height of fall. It will be seen that for all practical purposes the curves are coincident up to about 600 ft./min., and that even with the greatest height of fall, frictional effects only reduce the terminal velocity by about 10% below the theoretical value.

The vertical rails on which the specimen holder runs terminate inside the quench tank, just above thick rubber buffers, (actually sections of $1\frac{1}{4}$ in. diameter hosepipe) which the conductor blocks hit at the end of the descent. The quench tank has a shape designed to reduce splashing and turbulence when the specimen enters the quench, and is fitted with an immersion heater *Q* and circulating pump *R* (see Fig. 4). The pump may also be employed to feed water jets directed on the surface of the tinplate, the jets being either just submerged, or, if required, just above the water level in the quench tank. Water temperature is indicated on a dial thermometer *S* on the main control panel. The apparatus is enclosed by a wire mesh door during operation, the closing of the door actuating a mechanical safety stop which is designed to prevent accidental descent of the specimen holder when the door is open.

The electrical circuit is shown in Fig. 4. The nucleus of the control panel is formed by two non-cycling type electronic process timers, each of which may be adjusted by 0·1 sec. steps. The first timer *A* (uppermost in Fig. 1) controls the time of heating of the specimen *C* up to the moment of release : and at the completion of its own period it energizes both the second timer *B* (through the link(*A*-*B*) and the release solenoid *D*. As the sample falls, heating is continued under the control of the second timer for any desired period up to the time that the specimen enters the water quench *E*. The entire operation is thus automatically initiated on depressing the start button *F* of the first timer. The timer relays *G* and *H* actuate a 25 A capacity contactor *J* which allows the 5 kVA. 3-phase/1-phase, oil-cooled, step-down transformer *K* to be energised from the 440 V. mains supply. The transfer of the control of the contactor from the first to the second timer is rapid enough not to cause the contactor to break the circuit momentarily. The output voltage from the transformer may be varied by the tappings between 8 and 120 V., and normally an open circuit value of about 14 is employed for 90 lb. substance test-pieces. The usual total heating time for flow-brightening is then in the range 2–3 secs. The flexible leads *L* connected to the specimen holder are 1 in. wide earthing strip consisting of braided tinned copper wires. A current transformer *M* is placed around one of the transformer output leads and is connected *via* a two-way switch to either of two A.C. ammeters on

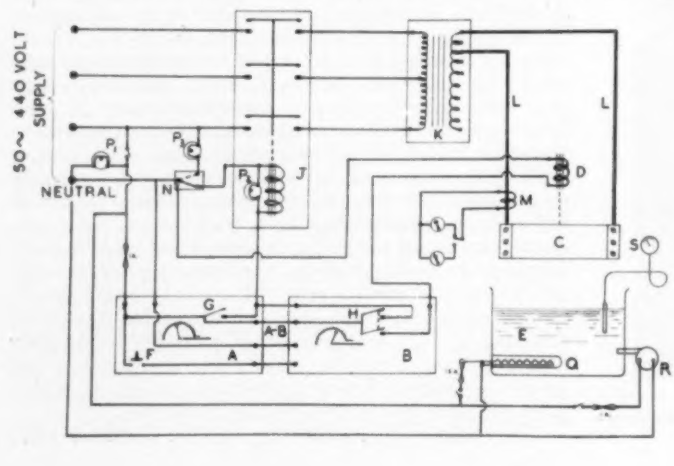


Fig. 4.—Electrical circuit of flow-brightening unit.

(a)

(b)

(c)

(d)

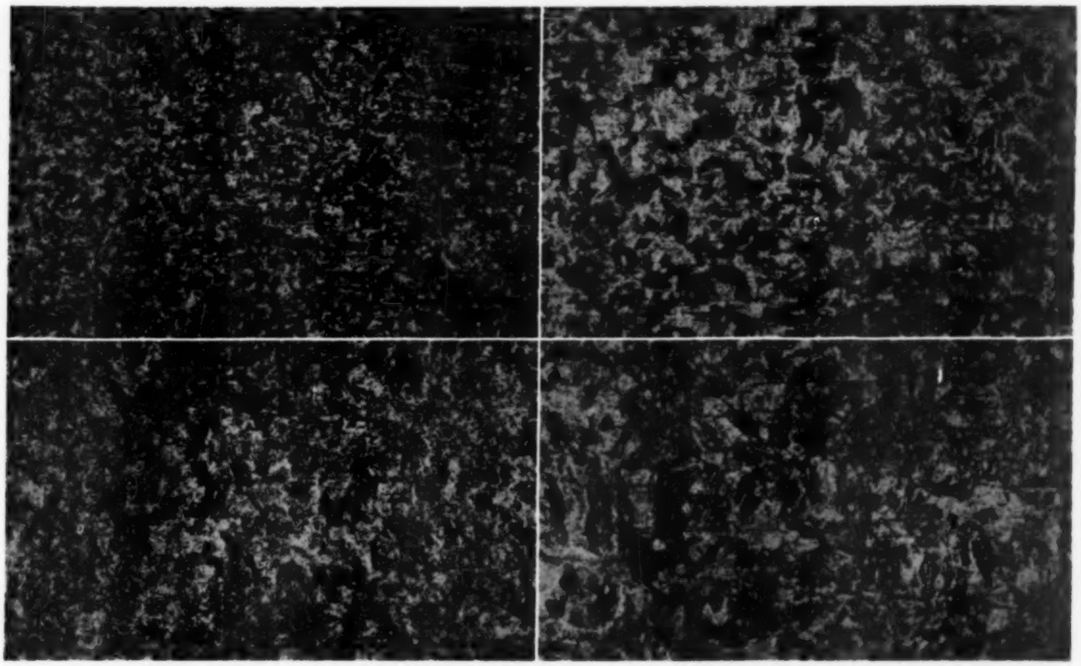


Fig. 5.—Samples of commercial electrotinplate : (a) 0·5 lb./b.b. from Halogen line (U.S.A.) ; (b) 0·5 lb./b.b. from Plant No. 1 (U.K.); (c) 0·25 lb./b.b. from Plant No. 2 (U.K.); (d) 0·75 lb./b.b. from Plant No. 2. (U.K.) × 4

the control panel. In this manner the current flowing during flow-brightening, usually about 1,600 A., is reduced by a factor of 160, and may then be indicated on normal A.C. ammeters having capacities of 10 or 20 A. for full scale deflection.

The safety cut-out micro switch *N* is of the non-return type, and therefore requires re-setting after each flow-brightening operation. It is situated alongside the guide rails just above the quench tank *E*, and automatically cuts off the heating current as the sample enters the water. This switch has a 10 in. long operating arm, which engages with a peg on the descending specimen holder and enables it to be positioned well clear of the water, thus avoiding electrical defects resulting from condensation on, or splashing of, the switch. When the switch is depressed by the fall of a specimen, an indicator light *P*3 glows on the control panel.

Grain Size of Tinplate Coatings

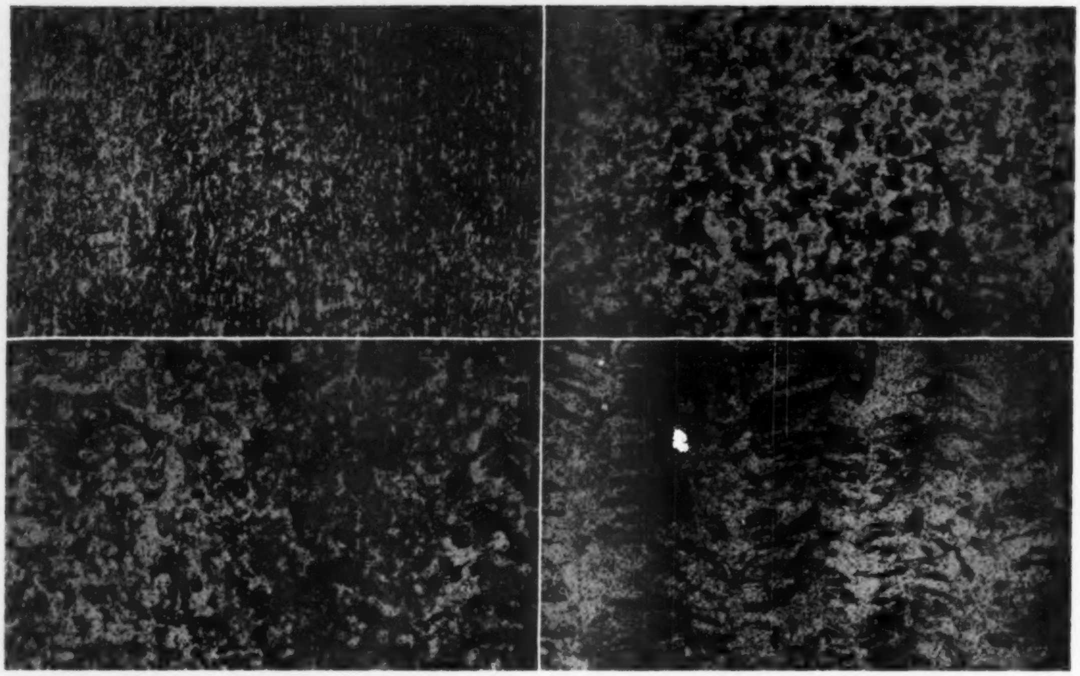
The crystallites or grains in the tin coatings of tinplate are, of course, platelets in which two of the dimensions are generally of the order of ten thousand times greater than the third. In addition, while the outer surface is substantially smooth, the interface between the free tin and the underlying tin-iron compound layer is extremely irregular. They must not be thought of therefore as having the same general shape as the crystals within bulk metals, which usually have axes of approximately equal size. It will be understood that the expression " grain-size of the tin coating " refers to that observed after etching the sample of the tinplate with a suitable reagent, such as an alcoholic solution of ferric chloride. The possibility of the outer surface of the coating showing a different structure from that adjacent to the compound layer must be borne in mind, however.

The grain size of the tin coating of tinplate varies within quite wide limits. In flow-brightened electrolytic coatings individual crystallites may be of the order of 1/16 in. across, or less, while in hot-dipped coatings crystallites may be several inches across, and in some cases have been found to extend from one edge to the other of a 30 in. long tinplate sheet.

The author is not aware of any published evidence that grain size affects the performance of a tin coating. It is generally known, however, that in the case of electrolytic tinplate, coarser grain coatings may be prefered for certain purposes, and means of influencing grain size are therefore of interest. Moreover, in preparing laboratory specimens of electrotinplate for investigational purposes it is desirable, in the interests of experimental purity, that grain size should be under some measure of control. In earlier work[2] the author had found some influence of flow-brightening temperature on coating grain size, but in these experiments the grains were dissimilar in shape and size to those encountered in commercial tinplate. The present experiments carried out on the new flow-brightening apparatus were intended to discover to what extent grain size could be controlled and which factors had the greatest influence.

The process variables may be conveniently divided into two groups, the first including conditions under which the flow-brightening is carried out, such as temperature of tinplate or of the water quench, and the second covering factors relating to the test-piece itself, such as tin coating weight, and pre-plating treatment.

For interest, and for comparison purposes, four



(a) (b) (c) (d)

Fig. 6.—Effect of total heating time on test-pieces quenched at 700 ft./min. in water at 50° C. : (a) 1·6 sec. ; (b) 2·3 sec. ; (c) 2·7 sec. ; (d) 3·1 sec. × 4

different samples of commercially produced 0·25—0·75 lb./b.b. (basis box) electrotinplate have been etched and are illustrated, magnified four times, in Fig. 5.

(*a*) *Effect of Flow-Brightening Conditions*

The possible variables during the laboratory flow-brightening process itself are :—

(*i*) Total heating time of the sample. This governs specimen temperature which corresponds, in an electrotinplate line, to temperature of the strip just prior to quenching.

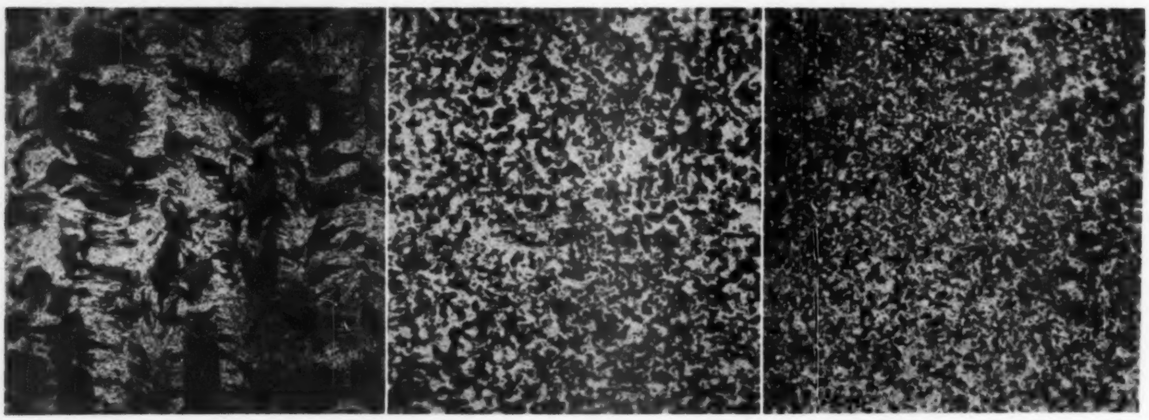
(*ii*) Height of fall of the test-piece, corresponding to strip velocity.

(*iii*) Temperature of the water in the quench tank.

(*iv*) Circulation of the water in the quench tank.

Laboratory produced test-pieces of nominal 0·50 lb./b.b. tinplate, plated in the circulating electrolyte cell, were flow-brightened and each of the first three variables was altered in turn.

The heating time before release of the specimens was varied from 1·3 sec. to 2·8 sec., while heating continued



(a) (b) (c)

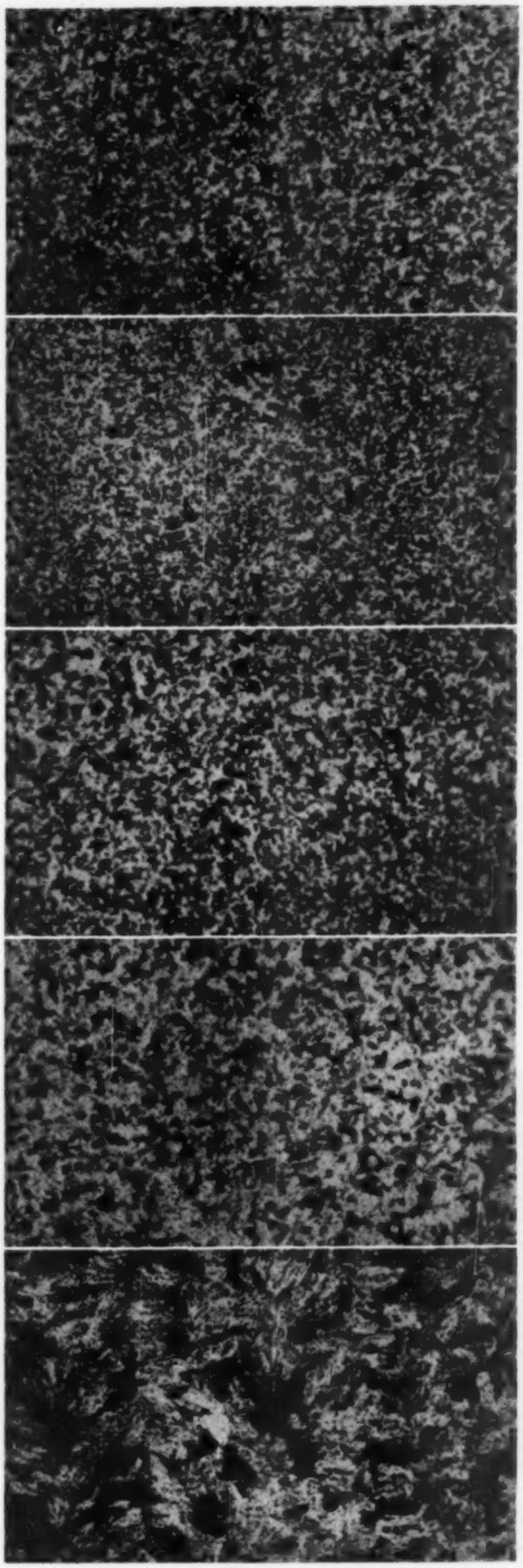
Fig. 7.—Effect of quenching speed on test-pieces quenched in water at 20° C., and all heated for a total time of 2·3 sec.: (a) 475 ft./min. ; (b) 700 ft./min. ; (c) 950 ft./min. × 4

during the fall (for a further 0·3 sec.) until the automatic cut-out switched off the heating current as the specimen entered the water : the terminal velocity of all the test-pieces was about 700 ft./min. The temperature of the water in the tank was held constant at 50 ± 2° C. Equipment is at present being installed for accurately measuring peak specimen temperature but has not yet been put to use. However, some idea of the temperatures involved may be obtained from the fact that with the minimum heating time (1·6 sec. total) some small parts of the tin coating remained unmelted, while at the maximum of 3·1 sec. total time, a slight yellow oxide film was formed, similar to that usually experienced at about 350° C. The marked effect of total heating time on tin coating grain size is illustrated in Fig. 6. An interesting feature is the distinct change in appearance of the grains with the longest heating time. The approximately equiaxed grains, obtained when using melting temperatures comparable with those in practice, giving way to a " columnar " arrangement of crystallites for a heating time of 3·1 sec.

It will be realised of course that, in normal electrolytic tinplate manufacture, the period for which the coating is molten is kept to a practical minimum, in order to minimize the growth of tin-iron intermetallic compound and to promote good appearance, and this practice may therefore result in the production of relatively fine grain size of the tin coating.

In the next series of tests, the total heating time was kept constant at 2·3 sec., but the height of drop was altered to give terminal velocities of 475, 700 and 950 ft./min. The heating time before release of the specimen was adjusted to allow for the different times of fall from each position. With the water-quench maintained at 50° C., or above, there appeared to be no significant effect of specimen speed. With the quench at 20° C., however, a speed of 700 ft./min. resulted in equiaxed type grains slightly larger than those produced at 950 ft./min., whereas at 475 ft./min. much coarser " columnar " type grains were obtained, (Fig. 7).

For any one quenching velocity, again with a total heating time of 2·3 sec., the tin coating grain size was found to increase with the temperature of the water quench, the effect becoming increasingly large the higher the temperature. Thus, for a specimen speed of 700 ft./min., there was no significant difference in grain size between specimens quenched at 3 and 10° C., but at 20° C. and above progressive increases were observed (Fig. 8). For a quenching temperature of 70° C., the " columnar " arrangement of crystallites was observed. For a quenching speed of 950 ft./min., the tin coatings obtained on test-pieces quenched at 20, 75, and 95° C., had the appearances shown in Fig. 9. The change in the type of crystals from equiaxed when quenching at 20° C. to " columnar " at 75° C., and then to structures resembling frost on window-panes when the water temperature was raised to 95° C., will be immediately apparent. The latter closely resembles the type of crystals in a hot-dipped coating. Comparison with Fig. 8 will show once again that for quenching temperatures of 20° C. or 70–75° C., varying speed between 700 and 950 ft./min. caused only a minor change in grain size.



(a)

(b)

(c)

(d)

(e)

Fig. 8.—Effect of temperature of water quench on specimens moving at 700 ft./min., and all heated for a total time of 2·3 sec. : (a) 3° C. ; (b) 10° C. ; (c) 20° C. ; (d) 50° C. ; (e) 70° C. × 4

(a) (b) (c)

Fig. 9.—As for Fig. 8, but specimen velocity 950 ft./min. : (a) 20° C. ; (b) 75° C. ; (c) 95° C. × 4

All the effects described related to quenching conditions in which the specimens were dropped into still water. By recirculating the quenching water through a row of jets just beneath the surface of the water and about ½ in. from each face of the sample, the dependence of tin grain size on quenching conditions could be greatly altered.

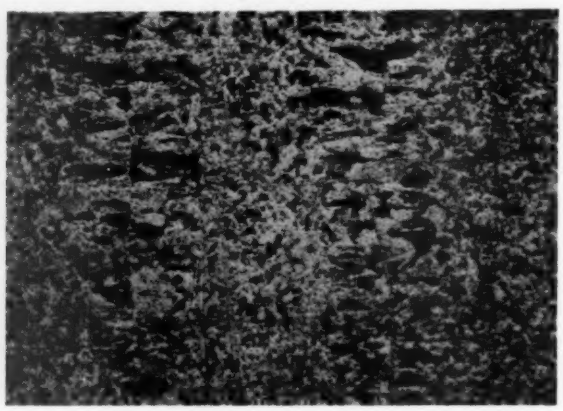
Submerged jets are, of course, provided in many electrolytic tinplate lines, and were installed in the laboratory apparatus in an attempt to increase the uniformity of tin coating grain size. Low pressure jets were found to reduce the overall grain size for any one given set of flow-brightening conditions, but did not substantially reduce the variation in grain shape and size. High pressure jets spaced ⅜ in. apart along the length of the test-pieces produced the interesting effect shown in Fig. 10 *a*, the " stripes " of lower reflectivity corresponding to the spacing of the water jets. On etching this surface (Fig. 10 *b*) it was found that the " stripes " were regions of extremely fine equiaxed grains, presumably resulting from the rapid chilling by the jets, while the bright regions in between the stripes were of considerably larger " columnar " type grains.

(b) Effect of Process Variables Prior to Flow-Brightening

A preliminary exploration was made of the effects of tin coating weight and steel preparation procedures on tin coating grain size. The effect of steel substance was not studied.

The effect of tin coating weight on the grain size of the tin coating was studied by plating 0·25, 0·50 and 1·0 lb./b.b. test-pieces and flow-brightening them under

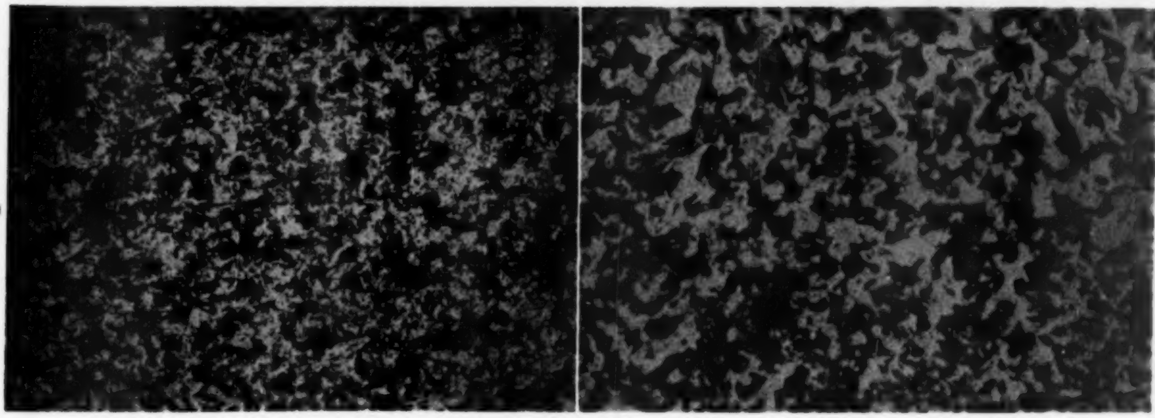
(a) × 4/5



(b) × 4

Fig. 10.—" Striping " effect resulting from use of submerged jets in the water quench : (a) as flow-brightened tinplate ; (b) etched to show that stripes result from regions of coarse and fine grains.

(a)



(b)

Fig. 11.—Showing only slight effect of coating thickness in specimens quenched at 700 ft./min. in water at 50° C., and heated for 2·3 sec. total time: (a) 0·25 lb./b.b.; (b) 1·0 lb./b.b. × 4

similar heating and quenching conditions. Fig. 11 shows the 0·25 and 1·0 lb./b.b. samples, from which it can be seen that there is only a slight increase in tin grain size as coating thickness increases. Generally, it was felt that such differences in grain size could not be counted as significant when the usual variation within single specimens was taken into account.

In a similar manner it was found that the amount of pickling of the steel prior to tinplating, when varied over the range usually encountered in electrolytic tinplate practice, resulted in no significant effect on tin coating grain size for 0·25, 0·50 and 1·0 lb./b.b. test-pieces.

Normal variations in the surface smoothness of the "as-received" steel appeared to affect the grain size to a small extent, but the effects were found to be rather inconsistent, at least in the small number of steel types available, and were considered to be insignificant.

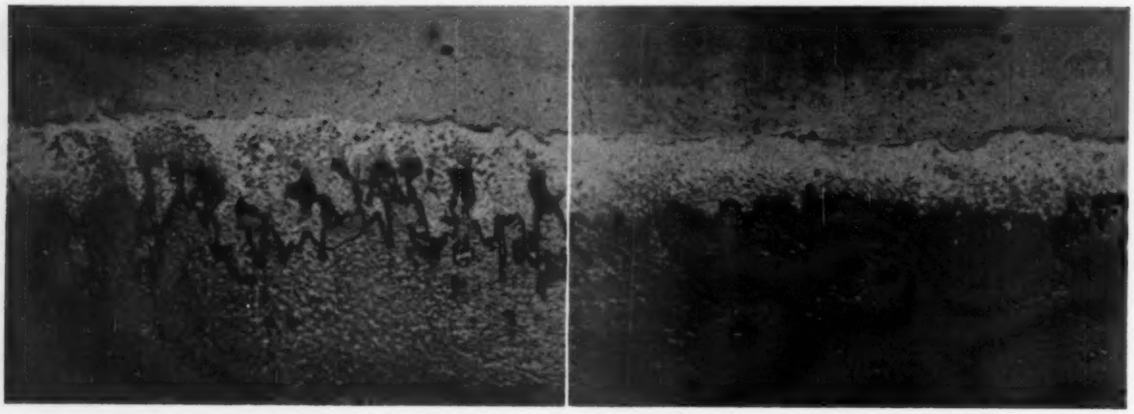
In the course of another research programme some steel blanks were chemically polished in a hot oxalic acid/hydrogen peroxide solution, prior to tinplating. Fig. 12 shows a piece of flow-brightened tinplate (note: at a lower magnification than the previous photographs) one half of which has been chemically polished while the other half has received only an alkaline cleaning treatment prior to tinplating. The large grains on the chemically polished part of the specimen are immediately apparent, suggesting that the nucleation of the tin crystallites depends to a rather large extent on the micro-smoothness of the underlying surfaces. Further experiments showed that if such polished surfaces were subsequently anodically pickled in the normal manner this, surprisingly, did not cause any substantial modification of the effect of the previous chemical polishing.

In addition, the previously described effects on tin grain size of flow-brightening conditions such as the quench bath temperature appeared to be modified some-

(a)

(b)

Fig. 12.—Difference in grain size between two halves of 0·5 lb./b.b. acid tinplated test-piece having (a) a simple alkaline clean (left-hand portion), or (b) a chemical polish and alkaline clean (right-hand portion) prior to plating and flow-brightening. × 1¼



(a) (b)

Fig. 13.—Taper micro-sections showing: (a) normally processed tinplate; and (b) steel base chemically polished prior to normal processing. × 1500 (in vertical direction)

what by the smoothing of the steel surface. Comparison under the microscope at high magnifications of taper-sections of tinplates with and without chemically polished steel bases showed that the "ridged" surface of the normal steel (Fig. 13 *a*) had been levelled to a large extent by the oxalic acid polishing solution, reducing the overall surface roughness to a very considerable degree (Fig. 13 *b*). It is interesting to note that some preferential dissolution at the ferrite grain boundaries had also occurred during the treatment.

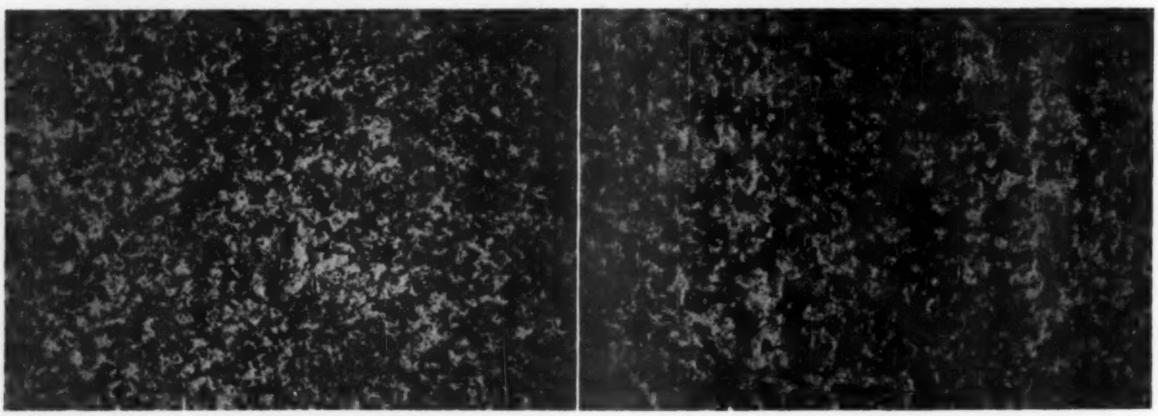
In another experiment a thin layer of pure iron was electrodeposited on to the cleaned and pickled steel surface prior to tin-plating. Under standard flow-brightening conditions the iron plating was found slightly, but consistently, to reduce the grain size. To obtain grains comparable in shape and size with those on a sample having no iron under-coat, the temperature of the quenching water had to be increased by a little more than 10° C. However, the application of an iron under-coating layer to a surface already prepared by chemical polishing did not influence the grain size of the tin coating, presumably since the iron deposit followed accurately the contour of the smoothed steel surface.

The final variable studied was the effect of type of tin-plating bath on the grain size of the coating. Fig. 14 shows that in 0·50 lb./b.b. samples, the same tin coating grain size was obtained with both stannate and acid type electrolytes when a normal plating pre-treatment was employed. However, whereas chemical polishing of the steel base caused a large increase in tin grain size when plating from the acid bath, as mentioned earlier, this phenomenon was not seen in coatings produced in a stannate electrolyte. This will be seen by comparing Fig. 14 *b*, showing the surface appearance of a flow-brightened stannate type plating using a normal pre-plating preparation, with Fig. 15, in which the steel was initially chemically polished.

Summary

A new laboratory electrotinplate flow-brightening unit has been developed and found to be flexible and versatile. In performance it was quite satisfactory and in this exploratory work only a few modifications have suggested themselves.

It has been shown that the grain size and shape in the tin coating of electrolytic tinplate may be influenced by



(a) (b)

Fig. 14.—Showing no significant effect of type of electrolyte on tin coating grain size in specimens quenched at 700 ft./min. in water at 50° C.: (a) acid stannous sulphate plating; (b) alkaline sodium stannate plating. × 4

a number of factors. Present experience is confined to laboratory tests, but the results suggest that strip temperature (which is governed by current input in the flow-brightening tower), strip speed, quench temperature, and circulation in the quenching tank may all affect grain size. Local temperature of the quench may well be the major factor. Tin coating thickness and original smoothness of the steel base affect tin grain size, but perhaps only to a small extent.

It is usual practice to operate a line at lower speeds for the heavier tin coatings than for the lighter grades, in order to obtain adequate plating time. The cleaning, pickling and flow-brightening times are thus increased, but correspondingly the currents can be reduced in order to maintain the coulomb density constant in the electrolytic processes and to prevent overheating during melting of the coating. The present experiments have suggested that both heavier tin coatings and lower rate of quenching may each be conducive to increasing the grain size of the coating. It is reasonable to assume that the two effects are additive, and that if all other manufacturing conditions were to be constant, the heavily coated tinplate might therefore have a larger grain size.

The discovery of the occurence of very large crystals in acid type tin coatings applied after a chemical polishing treatment on the steel basis may have quite wide implications. It is not certain from the experimental work in what manner the smoothing treatment influences the growth of the crystals in the tin coating, but it seems likely that a desired increase in grain size, and perhaps some additional measure of control over grain size, may be possible using a surface smoothing process prior to plating on the tin coating.

The phenomenon of "striping," produced by the use of high pressure water jets on the tinplate, needs to be investigated further, and is tentatively suggested as a method of identifying either the high or low coating face of differentially coated tinplate. Insufficient work has as yet been carried out to establish beyond doubt whether the effect can be consistently reproduced, and more experiments are envisaged. If successful, however, such a technique might form a simple procedure for marking differential tinplate.

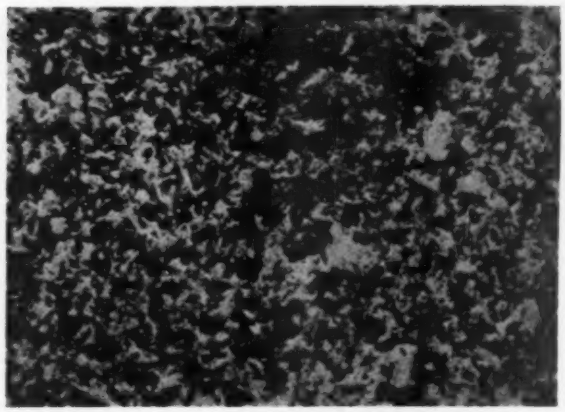


Fig. 15.—Alkaline sodium stannate deposit on chemically polished steel base. Note similarity in grain size to that on the unpolished basis in Fig. 14b. × 4

Acknowledgments

The author is indebted to the International Tin Research Council for permission to publish this paper, and to his colleagues for assistance in the experimental work.

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Aluminium Rolling Mill Ordered

THE largest rolling mill of its type in Western Europe has been ordered by James Booth Aluminium, Ltd., as the first part of its £5 m. re-equipment and expansion programme. It is expected to be in operation in the company's Kitts Green Works, Birmingham, during 1961. The mechanical side of the new plant, costing approximately £1½m., has been ordered from Loewy Engineering Co., Ltd. (Bournemouth, Hants.), and is designed to roll aluminium and Duralumin slab ingots weighting up to 6 tons, for the production of plate, sheet and strip. Included in the plant is a reversing 4-high hot mill 148 in. wide. Contracts for other equipment, which will make the Kitts Green Works one of the most up-to-date in Western Europe, will be placed shortly.

James Booth Aluminium, Ltd., was formed by the Delta Metal Co., Ltd., to acquire the aluminium interests of its subsidiary, James Booth & Co., Ltd., and earlier this year a 50% interest on the new company was acquired by the Kaiser Aluminium and Chemical Corporation of the United States.

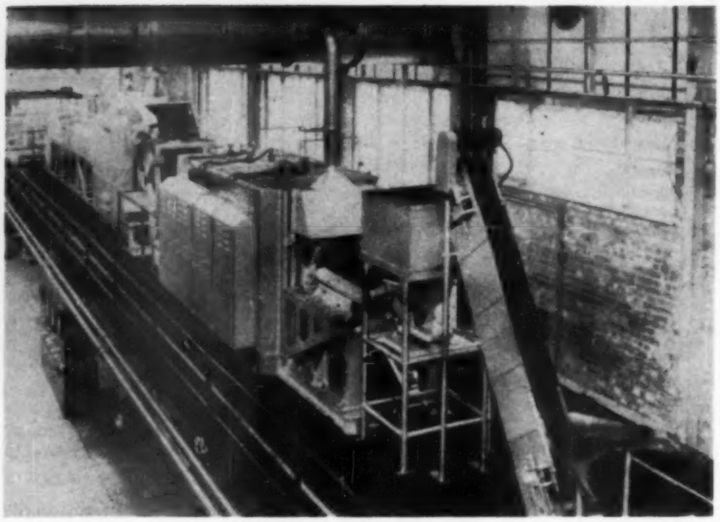
This is the first stage in a major development programme, it is stated by Mr. W. J. Vaughton, managing director, which is being carried out by a newly-formed team of specialised engineers under the direction of Mr. D. H. H. Clarke, engineering director of James Booth Aluminium, Ltd. As well as providing much larger sizes of aluminium alloy plate, particularly to meet the growing demands of the shipbuilding, chemical, aircraft and atomic energy industries, the new plant will greatly augment the production capacity for all flat rolled products.

Magnesium Industry Meeting

AT the invitation of the Magnesium Industry Council, the Spring Meeting of the Magnesium Association of America will be held in this country towards the end of May, 1960. The membership of the Association includes the majority of American firms interested in magnesium and its alloys, and there are also associate members in Europe. The meeting will open on the 23rd May with two days' presentation of scientific and technical papers, after which visits will be paid to foundries and works in the Midlands and in the Manchester area, where further papers will be read.

About sixty members of the Association, many of them accompanied by their ladies, are expected to attend, and the meeting will also be attended by representatives of the member firms of the Magnesium Industry Council. The president of the Magnesium Association is Mr. Otis E. Grant, president of Magnode Products, Inc., and the chairman of the Magnesium Industry Council is Mr. E. Player, managing director of Birmid Industries Ltd.

Automatic Heat Treatment of Bearing Rollers



General view of the production line for hardening and tempering rollers. The tempering furnace is on the left and the control panels are mounted on the floor beneath the overhead platform.

THE fitting of roller bearings to goods rolling stock as part of the British Railways modernisation plans has led to the installation of new heat treatment plant at the East Works, Daventry, of British Timken. The plant is arranged as a continuous production line in which Efco furnaces automatically harden and temper the rollers after deep gas carburising. The line includes a shaker hearth furnace with quench tank and electrically operated charge elevator, an endothermic atmosphere generator and a mesh belt conveyor furnace, all manufactured by the Electric Resistance Furnace Co., Ltd. Between the quench tank and the mesh belt furnace there is an Efco washing machine designed and manufactured by the Electro-Chemical Engineering Co., Ltd. With the exception of the quench tank and control gear, the production line is installed on an overhead platform, conserving floor space and allowing the quench tank to be accommodated beneath the hardening furnace without excavations.

Hardening

The rollers to be heat treated are carried by an electric elevator into a hopper which feeds them on to the oscillating hearth of the hardening furnace. This hearth is 18 in. wide and is made in a nickel-chromium alloy. It is actuated in one direction by an electric motor driving an operating cam, and in the other direction by a spring return mechanism. The operating frequency can be adjusted to vary the speed of travel of the parts through the furnace and to allow heating times up to one hour.

The rollers enter the furnace chamber through a short heat-insulated vestibule fitted with a fume removal hood and having a vertically rising door to allow adjustments to be made to the height of the furnace entrance. The chamber is 8 ft. long and is heated by electric radiant tubes. The elements are positioned above and below the hearth and can be withdrawn quickly and easily from one side of the furnace without having to close down the furnace. They are arranged in three independently controlled zones, each having its own automatic indicating controller, and the temperatures are recorded on a three-point instrument.

The heated rollers leave the furnace by a discharge chute and, to ensure quenching from the full hardening temperature, they immediately enter an oil weir on the chute itself. The oil pumped to the weir travels with the rollers into the quench tank, which is an independent and self-supporting unit fitted with overflow and oil circulating connections.

An electrically operated elevator having an endless, perforated, steel conveyor belt fitted with cross flights carries the quenched rollers to the washing machine. Here in a single stage, gas heated machine, the quenching oil is removed with a hot detergent spray. The machine is fitted with a wire mesh conveyor belt from which the cleaned rollers pass down a chute to be distributed evenly by guide rails on to the tempering furnace conveyor.

Tempering

In the tempering furnace the rollers are heated by forced circulation of an air flow which is directed with baffles from a fan in the roof, over heater banks, and through the 20 ft. long chamber. The furnace has a double casing enclosing the heat insulation, and the heater banks, consisting of nickel-chromium wire spirals on frames, are also mounted in the roof. Temperatures are automatically controlled with a two-point instrument.

The shaker hearth furnace provides temperatures up to 950° C., and has a total rating of 63 kW. It is supplied with a controlled atmosphere, produced in an Efco generator by the endothermic process, to keep the rollers free from decarburisation. The tempering furnace normally operates at 160° C., but temperatures up to 300° C. are possible : it is rated at 50 kW.

The complete installation was designed to provide a minimum output of 100 lb. of $\frac{3}{4}$ in. diameter rollers an hour, including a soak period of one hour. Without this soak period the output of rollers is 200 lb. per hour, and for a different type of product, could be as high as 300 lb. per hour, depending on size to weight ratio, etc.

Aluminium and its Alloys in 1959

Some Aspects of Research and Technical Progress

By E. Elliott, A.Met., F.I.M.

Chief Metallurgist, The Aluminium Development Association

Attention is drawn to work published in this country and the U.S.A., reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution, properties and standardisation. Reference is also made to interesting applications of these materials.

(*Continued from page* 69 *of the February issue*)

Joining (*Continued*)

Whenever a particularly virulent poison is discovered, medical men usually devote attention to its use in very small quantities in the treatment of disease. Similarly, gases which alone are useless as shielding media in welding are attractive to welding technologists as additions to inert gases. Allen[79] has developed what he calls the inert-plus-nitrogen-gas metal-arc process for pure aluminium and aluminium alloys without large contents of magnesium. He passes inert gas through the contact tube of the welding gun, and about three times the volume of nitrogen through the gas nozzle, and cheapens the welding process considerably. Work in Russia on weld pool temperatures has been described by Rabkin[80]; in automatic MIG welding, he finds that the forward extension of the pool varies little with the welding speed, but depends on arc current, while sharp changes in temperature occur at the front part of the pool.

After the feast, the reckoning, and after the welding, the assessment of quality. Tranter[81] has discussed the tests used to establish standards of acceptance in aircraft welding, including tensile, shear and bend tests, metallographic examination and the detection of defects, many of which are depicted in some excellent illustrations. In an old but still popular children's story, " Five Children and It," by E. Nesbit, the quintet referred to face the difficulty of testing fireworks, in that after test the subject tested is no longer available. Lismer[82] has grasped a similar nettle in connection with welding ; the tests he describes include tensile, bend and impact, and he refers to the use of welded aluminium alloys at sub-zero temperatures.

Several articles have appeared on pressure welding, a process which seems to offer so much in the joining of aluminium, but which has not enjoyed very wide application. The suitability of aluminium for cold welding is brought out by Rollason[83] in two tables. In the first, listing metals in order of their relative cold weldability, aluminium and its alloys occupy the first five places, and in the second, giving minimum pressures, only tin requires less than aluminium. Donelan[84] has described commercial cold pressure welding, and examples with aluminium include cable lugs and a kettle made by joining two pressings. Vaidyanath and his co-workers[85] have studied pressure welding by cold rolling, and concluded that a deformation of 60–70% is needed with aluminium to give 100% weld strength. Bonding is promoted by the use of low rolling speeds and large-diameter rolls. Some permanent bonding between metal surfaces was produced by relative movement of overlapped strips under compression in work by Holmes[86] but this did not aid the attainment of maximum joint strengths by subsequent direct indentation.

Fortunately, the engineer concerned with joining aluminium is nowadays offered many processes from which to choose, but this happy state of affairs brings one difficulty in its train ; how to select the optimum technique Houldcroft and Burgess[87] have helped to solve this problem by discussing the merits of the various methods of welding, brazing and soldering, and have provided examples of industrial applications, including illustrations of welded assemblies. Hackman[88] has also surveyed the welding of aluminium and its alloys and made suggestions as to the methods to be used in such fields as aircraft, missiles, pressure vessels and bridges. Another important sphere of operation is the shipyard, and in an article on automatic welding in ship construction, Shaw[89] makes special reference to aluminium, and describes equipment used in the prefabrication of deck-house components and superstructures in aluminium-magnesium alloys. Burgess[90] has surveyed the welding of aluminium in the construction of rail vehicles, both in this country and abroad ; although progress has been made, there is great scope for wider adaption of aluminium alloys by the railways, in both coaching and rolling stock. With the reduction in production of military aircraft, the manufacturers of aeroplanes are diversifying their activities, and their knowledge of aluminium and its alloys has stood them in good stead. An account has appeared of the fabrication and welding by one such company of large equipment in aluminium alloy for nuclear applications,[91] including joints in aluminium-magnesium alloy plate as thick as 5 in. Tanks for the transport of liquids at sub-zero temperatures must be of material not subject to brittle fracture ; Coen[92] has designed special extrusions for the support and stiffening of such vessels in aluminium-magnesium alloy, and discussed the welding processes used in fabrication of tanks and supporting structure.

Aluminium alloy milk churns[93] are increasing in popularity and their construction in heat-treatable alloy by automatic tungsten arc welding has been described. In North America, aluminium alloy tubes are securing a place in the construction of pipe-lines, and Saunders[94] has developed a portable pipe-welding machine for joining them, involving the MIG process.

An important complement to the welding of aluminium is the method whereby joints may be made without melting the parent metal, namely brazing. This is applicable by three principal methods, torch brazing, furnace brazing, and flux-dip brazing. The principles and practice of these three processes[95] have been described and discussed, and indications given of the types of joints which may be made, and the strength properties to be expected. The soldering of aluminium is less frequently practised, but high zinc solders offer a process midway between brazing and soft soldering, and give a joint of good corrosion resistance. Singleton[96] uses abrasion soldering without fluxes to attain such joints in small sections of heavy gauge, but concludes that large section or thin material require considerable skill and experience. The joining of aluminium to uranium by soldering was tackled by Mishler[97] *et al* by plating the uranium with chromium, iron or nickel, to serve as a diffusion barrier, and then with a copper flash, and plating the aluminium with copper.

Dissimilar metals must often be joined to each other in engineering, but not commonly by fusion methods. Young and Smith[98] have discussed the metallurgical principles involved and practical examples of bimetallic joints are cited. Aluminium is welded to steel after coating the steel with aluminium by metal spraying or hot dipping. Aluminium to copper joints are readily made by flash-butt welding or by cold pressure welding.

Constitution

Every metallurgist interested in aluminium alloys will welcome the publication of Phillip's monograph[99] on equilibrium diagrams of important systems involving aluminium. It consists of diagrams with notes of 20 binary and 12 ternary systems, almost all having relevance to commercially important alloys, and represents current thought throughout the world, as may be seen from the references quoted. The author is to be congratulated upon his work, but it is a pity that his publisher did not give the diagrams a little more space, to enable the more detailed areas to be studied more accurately.

Phillips covers neither the aluminium-lithium nor the aluminium-thorium systems, and indeed they may be considered of little general commercial importance. Recently interest has increased, however, in aluminium alloys containing lithium, in view of claims for their good strength at elevated temperatures, so that work by Jones and Das[100] on the solid solubility of lithium in aluminium has a degree of topicality. They find that the alloying element behaves as do a number of others ; a solubility of 4·2% at the eutectic temperature, just above 600° C., falls to 0·4% at 200° C. Turning to thorium, Harwell has a programme for investigating the alloying behaviour of this element, as part of which Murray[101] has studied the aluminium-thorium system and presents a proposed equilibrium diagram over the whole range. Aluminium is only slightly soluble in thorium, but a series of intermetallic compounds occurs, varying in composition from Th_2Al to $ThAl_3$.

Harding and Clare[102] have investigated Raynor's report of the occurrence in the aluminium-manganese-nickel systems under non-equilibrium conditions of a metastable phase Y, in addition to X ($Ni_4Mn_{11}Al_{60}$) and the intermediate phases $MnAl_6$ and $NiAl_3$. Their examinations of annealed and slowly cooled alloys revealed no trace of Y ; the authors conclude that it does not exist and that what had been previously identified as a separate phase was possibly secondary deposits of X, which on further annealing gave coarser crystals of this phase.

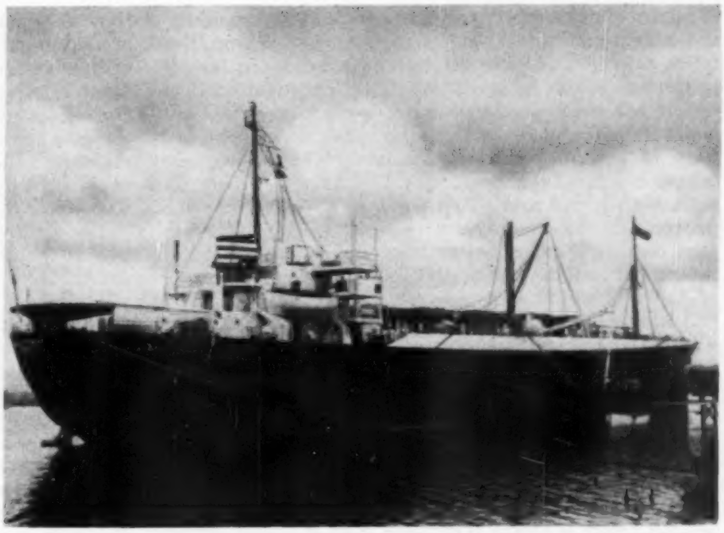
Properties

A number of papers have been published in the past few years in the U.S.A. extolling the increase in elongation or strength which may be obtained in aluminium-silicon-magnesium and aluminium-silicon-copper-magnesium alloys by reduction in impurity contents, especially iron. Reinemann and Marsh[103] have tested an aluminium–7% silicon-0–3% magnesium alloy based upon aluminium of high purity, and shown that, fully heat treated, it has greater elongation but lower strength than similar alloys with a copper content. Sodium modification was found to be of value only in sections where freezing was slow, when it increased elongation. One reaction to this work is to wish for similar investigations of alloys LM8 and LM16 based on high purity metal.

In a general article on non-ferrous casting alloys, Reichenecker[104] drives home a fact which should be engraved on the heart of any designer using castings—the test bar properties will not necessarily be obtained in all parts of the casting. He goes on to discuss the effect on strength properties of section size, temperature and soundness, and to suggest methods of improving the strength of castings, such as judicious use of chills, non-destructive testing, and cut-up tests on castings at the design stage. Much of this may seem obvious, but it is well for it to be set forth from time to time, to keep it in the forefront of the designer's and user's thoughts. Frear[105] is also concerned with quality in castings, and how best to represent them by test bars ; he draws attention to the disadvantages of cast-on test samples, and discusses the best form for those cast separately. His classification of castings according to properties required contains five grades, from those subject to very high internal pressures to castings purchased only for their weight or bulk—the lowest of the low, but a class into which many castings fall.

An important modern test of quality is that involving the use of ultrasonics. Working with high strength aluminium-silicon-magnesium alloy cast plates, Smolen and Rosenthal[106] have shown a definite increase in ultrasonic attenuation away from a chilled edge. With samples of aluminium–5% silicon alloy with various gas contents, attenuation was shown to be markedly effected by the presence of gas and micro-shrinkage, and it is suggested that ultrasonic inspection could be used to distinguish high quality from ordinary aluminium alloy castings. Hitt[107] describes the ultrasonic testing of aircraft forgings, and refers to the extension of the process to the detection of lack of adhesion in metal-clad honeycomb material used in aircraft structures. In a general review of the applications and working of honeycomb sandwiches, Newell[108] compares weights and costs of the various metals used, and also gives in tabular form the properties of several grades of honeycomb made from foil in the aluminium-manganese alloy N3, varying in thickness from 0·001 to 0·004 in.

The complex mechanisms of precipitation in aluminium alloys continue to attract investigators and Thomas and Nutting[109] have used the electron microscope to examine thin foil samples of high strength aluminium-zinc-magnesium-copper alloys of high and of commercial



The "Methane Pioneer": this converted tanker has vessels in aluminium alloy for the carriage of liquid methane.

purities. They show that ageing sequences are independent of alloy additions other than magnesium and zinc, and that chromium seems to promote uniform distribution of precipitates and to prevent sub-boundary formation. Confirmation is given that intercrystalline embrittlement at maximum hardness is associated with preferential slip in the denuded zones near grain boundaries. With Nicholson,[110] these authors have applied the same thin foil technique to alloys of aluminium with copper, silver, zinc and magnesium, solution treated, and after various ageing treatments. They describe the breakdown of the super-saturated solid solutions to give zones and precipitates, and discuss the functions in precipitation of vacancies and dislocations. Hirsch[111] also uses thin foils and transmission electron microscopy to examine dislocations in several metals, including aluminium. He demonstrates glide, partial dislocations, stacking faults, cross slip, and a number of other imperfections in structure; the illustrations of these are particularly impressive.

Prakash and Entwistle[112] have studied the effect of size of specimen on the ageing after quenching of a high-purity aluminium-copper alloy, and concluded that the lower hardening rate of large specimens is traceable to failure to retain vacancies. In further work with Williams[113] on a commercial aluminium-copper-magnesium alloy, Entwistle has measured the damping capacity of wires during ageing, and illustrated two distinct damping contributions, both evident only at an intermediate stage during the ageing process. The relevance of these to the ageing mechanism is discussed. Working with aluminium–30 to 40% zinc alloys, Watanabe and Koda[114] have shown that nodules formed by the grain boundary reaction were gradually dissolved, although the advancing boundaries scarcely changed their positions.

Returning to applications of the electron microscope, Cuff and Grant[115] have used shadowed replicas to illustrate a network structure on the surface of chemically polished aluminium of super purity grade, which they conclude to be a surface manifestation of an underlying three-dimensional network. Even purer metal, containing 99·999% aluminium, was used by Hrivnakova[116] in his electron microscopic investigation of the effect of cold working on block structure. Fragmentation is shown to occur in areas of maximum creep. The electron micrographs, oxide and carbon extraction replicas at 9 to 10,000 magnification, are magnificent, and those of the undeformed block structure are enough to make any keen rock-climber reach for his boots, and begin a mental classification into easy, moderate and severe.

Clad aluminium alloys are nowadays familiar, and it is interesting to read in an article by Porter[117] that the first commercial clad product, Alclad 17S, was produced in America as recently as 1928. The subsequent three decades have seen a great extension of product and application, and Porter summarises these, and also gives a full account of the special properties of clad materials. Goetzel[118] has provided a "state of the art" review of dispersion-strengthened alloys, with particular reference to SAP and APM; he lists the special properties of these products, including their strength at high temperatures and creep resistance, and envisages increased application of materials based on atomised alloys. Mori[119] has studied the properties of a number of aluminium alloys at sub-zero temperatures down to $-200°$ C., including pure aluminium, aluminium-magnesium, aluminium-copper-magnesium, aluminium-magnesium-silicon, and aluminium-zinc-magnesium-copper alloys. He finds that all these materials show increased strength and proof stress at low temperatures; elongation of non-heat-treated alloys also increases, but with heat-treated materials it decreases slightly.

Fatigue studies continue, both fundamental to determine the mechanism of failure, and more practical to assess the effects of variables upon endurance. Using transmission electron microscopy, Wilson and Forsyth[120] have studied the substructures produced by fatigue in super purity and commercial purity aluminium. They give an illustration of sub-boundary zones at a magnification of 27,500, showing a high density of defects, and spots which may be embryo voids or cracks. Polmear[121] is engaged in tests to investigate the theory that the reactions of solute atoms with dislocations, reducing their mobility, might improve the fatigue resistance of age-

hardened aluminium alloys. His work is with aluminium-zinc-magnesium alloys and those with magnesium/zinc ratios at a critical value seem to have improved fatigue properties, which he is continuing to investigate. Dugdale[122] has used rotating bending tests to ascertain the effect of residual stress on the fatigue resistance of notched bars of several materials, including the aluminium-copper-magnesium aircraft alloy L65. For this material, with both round and sharp notches, pre-stretching improved and pre-compression reduced fatigue life. Surface condition is known to have important effects on fatigue resistance; Finney[123] has subjected specimens of the aluminium-zinc-magnesium-copper alloy D.T.D. 683 and the obsolete aluminium-copper-magnesium alloy 2L40 to a number of pickling treatments and to anodising before fatigue testing. He concludes that caustic soda pickles give fatigue strengths superior to those obtained with acid pickles, while chromic acid anodising improved the fatigue resistance of 2L40, but reduced that of D.T.D. 683.

It is well known that joints have an important effect upon fatigue resistance, so that Newman's[124] paper on welded joints in alloys HE30 and NP5/6 is particularly welcome. This author stresses the need for further work before general conclusions can be drawn, particularly upon such factors as influence of porosity. The geometry of the weld largely determined fatigue behaviour, so that the welding process is not necessarily a significant factor. Koziarski[125] contrasts design for good fatigue life in riveted joints with welded joints; he notes that the latter should be in tension or compression, not shear or bending. Ultrasonic welding is considered to offer great opportunities for structural joints, but much development work is necessary.

Fatigue testing at large numbers of reversals takes a long time, and is therefore costly. Attempts to speed up testing are therefore to be encouraged, and McKeown[126] has continued his experiments with progressive loading, that is, steady increase of load on the outer end of a rotating cantilever specimen until fracture occurs, the stress then being related to endurance limit. McKeown has used this test to assess notch resistivity and directionality in fatigue in extruded L65 and D.T.D. 683.

The surface of aluminium, particularly when smooth and bright, is a very poor emitter of radiant heat, and a correspondingly good reflector of it; it is upon this that the value of aluminium foil as an insulating medium depends. Elliott and Parsons[127] have discussed the properties of foil in this context, and illustrated its application in the heat insulation of buildings, particularly industrial buildings now covered by the Thermal Insulation Act.

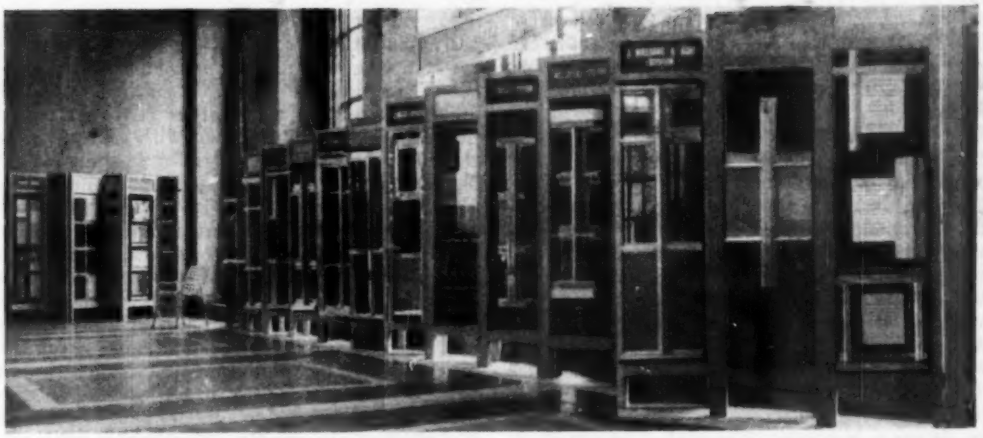
Corrosion and Protection

Aluminium, according to its detractors, is "just electrified dirt." Nevertheless, it resists strongly any return to its base origin, and by means of its wonderful oxide skin wards off the attack of many—indeed most—aggressive media. Porter[128] has brought this out clearly in a general account of aluminium, its alloys, and their corrosion resistance. This article is a masterpiece of compression, and forms a complete guide to the durability of aluminium in atmospheres, waters and chemicals, and to methods of protection. Hine,[129] while noting the high corrosion resistance of aluminium and its alloys, describes the investigation of failures when they occur by examination of corrosion products. This is real detective work, and out of 130 cases summarised only 30 remain unexplained; as many as 50 are put down to an aggressive agent detected in a normally suitable environment. In considering the mechanism of atmospheric corrosion of non-ferrous metals, including aluminium and its alloys, Aziz and Godard[130] point out the vital role of moisture; its accomplices are atmospheric pollutants, of which sulphur dioxide is the arch conspirator, with sea salt close behind.

Haggard and Santhiapillai[131] have studied preformed pits in pure aluminium in sodium chloride solution, and shown that pit growth is due not to the low *p*H of the pit solution, nor to chloride ion concentration, nor primarily to oxygen deficiency, but to the specific ability of aluminium chloride solutions to activate passive aluminium. Study of artificial pits is advocated by Greene and Fontana[132] in their general analysis of pitting corrosion. Perhaps their most significant conclusion is worth quoting in full, to avoid over-confidence and *pour encourager les autres*. It is: "There are no completely satisfactory theories of pitting corrosion." There is still opportunity for some latter-day Robert Boyle or mute inglorious Avogadro. Pitting may seem even desirable when compared with the rapid destruction of metal which can result from intercrystalline attack; Schafer[133] and his co-workers have tested corroded samples of aluminium-copper-magnesium alloy and shown that where intergranular corrosion has occurred in service, the same type of attack was obtained in the test solution. The authors relate their results to their previously published theory of corrosion involving gas evolution.

Two articles[134] under the same title in one journal issue are concerned with the corrosion of aluminium in liquid water at high temperatures; Trautner deals with the role of the film of corrosion products, and Dillon with the relationship between uniform corrosion and time. The nature of the film is discussed; it is shown to be duplex, a thin compact barrier film adjacent to the metal and a thicker more permeable bulk film. Temperature increase alters the relationship between corrosion and time; it progresses from logarithmic through parabolic to a linear dependence. In yet another article, Trautner[135] describes electron microscopic examinations of corrosion product films, by which he shows that corrosion inhibition is associated with different crystalline structures in the film. Perryman[136] has experimented with aluminium-nickel-iron alloys in high temperature water, and shown that attack in static water occurs about eight times as rapidly as in moving water, although prior treatment in static water will reduce corrosion in flowing water to about a quarter.

Turning to liquids at more usual temperatures, a good deal of interest attaches to the effect on metals of glycol-water cooling solutions. Dempster[137] has shown that the presence of only small quantities of copper in such solutions can cause severe attack of aluminium-magnesium alloy, but that additions of sodium tetrasilicate and tetraborate, with or without sodium cinnamate, are effective inhibitors of this corrosion. Seeking corrosion inhibitors in glycol solutions principally for cast iron, Mercer and Wormwell[138] find that additions of 5% sodium benzoate and 0·3% sodium nitrite protect also several other metals, including an aluminium-copper-magnesium-silicon-nickel casting alloy. Cessna[139] has used an electrical resistance method to evaluate corrosion inhibitors in glycol anti-freezes. He reports the



Comprehensive display of curtain walling systems in aluminium, on view on the occasion of the Aluminium Development Association's Symposium on Aluminium in Building, held at the premises of the Royal Institute of British Architects in July 1959.

rate of attack on aluminium of uninhibited anti-freeze to be low, but to increase with addition of chloride, sulphate and bicarbonate. Sodium metasilicate and polar-type oil were effective inhibitors; lack of success with sodium benzoate and sodium nitrite may be due to the low concentrations used (0·01N). Inhibition of the corrosion of aluminium by caustic soda solutions is a difficult problem; Sundararajan and Char[140] find that the optimum concentration of dextrin in 0·3 N alkali is high, namely about 10 g./litre.

The application of aluminium to cooling towers is not at present general in this country, although equipment to perform this function is the subject of experiment. In America some experience has been accumulated, and Haygood and Minford[141] have described it in a paper which also deals with alloy selection and water treatment. Clad aluminium-manganese alloy is favoured for this application. Mason and Schillmoller[142] discuss the effect of sulphide-bearing foul waters from oil refineries on a number of metals; aluminium is resistant to the sulphides, but liable to attack by chlorides, formic acid and copper salts which may also be present.

As a result of the presence of sodium silicate, acting as an inhibitor, solutions of commercial detergents may be less corrosive than certain tap-waters. This was revealed by an electrical resistance method of testing by Smith and Hadley[143] who also found that aluminium-silicon and aluminium-silicon-magnesium pressure die casting alloys were superior in durability to diecast zinc alloy. Rogers and Chinn[144] have performed a signal service by recording their experiments with aluminium-framed minesweepers and examinations of operational vessels. Their conconclusion is that more education of ship's companies is needed, as personnel have not yet appreciated the precautions necessary with aluminium alloy.

The publication by Dix, Anderson and Shumaker[145] of their views on the effect of temperature on the corrosion resistance of aluminium-magnesium alloys is a notable event. An important conclusion reached is that alloys containing more than about 3% of magnesium, if exposed in the cold worked state to moderately elevated temperatures, are susceptible to grain boundary precipitation of what in this country is termed the β-phase, and stress corrosion cracking may follow. This view is based principally upon laboratory tests, and the lack of service failures in aluminium-magnesium alloy ship's structures, which are exposed to mildly elevated temperatures in tropical service, must be set against such laboratory work. The views of such eminent and experienced corrosion experts must lead to further examination of this phenomenon, although there is long and satisfactory experience in this country of aluminium-magnesium alloys in ships.

Turning from corrosion to protection, note must be taken of an event that startled the country during 1959. A young lady who for about a quarter of a century had never felt the need for protective coatings suddenly left the national stage; Jane disappeared from the *Daily Mirror*, leaving behind her for many of mature age a feeling of *fin du siècle*. *Sic transit gloria mundi.*

The spreading application of anodised aluminium, especially in building and in decorative bright trim, has increased the number of papers devoted to anodic oxidation. Flusin[146] has presented a general discussion of the anodising process, and considered the effect on the final finish. Exercising again his skill in condensation, Porter[147] classifies all the standard aluminium alloys, both wrought and cast, according to their suitability for protective anodising, and also lists the available processes, the properties of the product, test methods, and applications. Brace[148] is concerned only with automatic anodising; he describes some existing installations, and considers the problems that must be overcome in applying automation. Outdoor exposure of coloured anodised aluminium demands dyes of high fastness to daylight, and Spooner[149] has traced the development of a selected range of shades. He also discusses suitable tests for light fastness and the effects of other factors such as sealing.

Realisation of the importance of efficient sealing of anodic coatings has increased over the past few years. McLennan[150] has removed sulphuric acid films from the metal by the iodine-methanol method, and, by measurement of impedance characteristics, has shown that sealing in hot water or steam causes partial blockage of film pores, and that boehmite is formed by hydration of the oxide film. Confirmation of this comes from Hinde[151] *et al*, working with boric acid films stripped by the mercuric chloride method, who showed that boehmite

formation proceeds independently of the presence of aluminium. Kape[152] has also conducted extensive experiments on sealing, and concludes that the best methods are in boiling water or steam, with a preference for the former.

According to Hérenguel and Lelong,[153] "hyper-hotworking," the phenomenon experienced in direct extrusion in zones where the metal deforms with a high rate of shearing, results in the dissolving of phases normally out of solution, followed by very fine precipitation. Such material has improved resistance to corrosion and very regular response to anodising. Simmons[154] has announced a new chemical brightening process for aluminium and its alloys, suitable for materials of normal and of high purity base. The solution used is basically diluted hydrofluoric acid, with additions which are not specified.

After a decade in the wilderness, vitreous enamelling of aluminium is again attracting a good deal of attention. Lister and Stephenson[155] have noted this increase in interest, and presented a brief account of the advantages of vitreous enamelled aluminium, including abrasion and scratch resistance, colour fastness, and resistance to corrosion by the atmosphere and by chemicals. The technique of vitreous enamelling of aluminium is described by Vickers[156] with special attention to castings. Avoidance of sharp corners is important and soundness vital; magnesium as an alloying element is undesirable, and copper in some doubt.

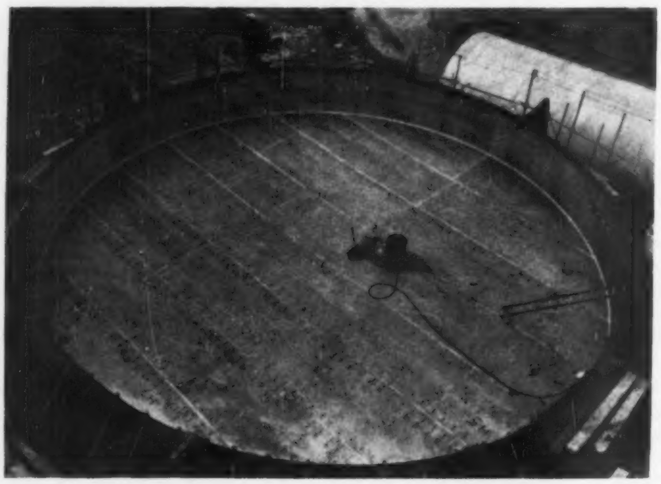
The position of vitreous enamelling in the U.S.A.[157] (they call it porcelain enamelling) has been summarised. Some reference is made to aluminium, but the article is chiefly noteworthy for its emphasis on techniques designed to produce attractive results; certainly some of the illustrations suggest beautiful effects. Dolphin Court[158], in Hove, is decorated with fluted panels in aluminium coated with vitreous enamel in greenish blue and pale yellow. A description has been published[159] of the pretreatment and enamelling of these panels.

True to its reputation as a modern, liberal, generous metal, aluminium is glad to protect its less fortunate fellow metals, particularly iron and steel. Coburn [160, 161] has explained the stage reached by hot-dip aluminised steel in the U.S.A.; he considers two types, with 0·001 in. and 0·002 in. coatings of aluminium. Maximum service temperature is stated to be several hundred degrees higher than with galvanised steel, and the corrosion life in industrial atmospheres of the more heavily coated type is at least three times that of 1 oz./sq. ft. galvanised sheet. With sprayed metal coatings on steel, Hoar[162] considers that aluminium has the advantage in acid industrial atmospheres, while the balance is slightly in favour of zinc in marine atmospheres, although experience of aluminium coatings by the sea is limited. Recent work by the American Welding Society[163] does not support the superiority of zinc spray in marine exposure. Bare aluminium-sprayed panels exposed to marine atmosphere were in at least as good condition after three years as zinc-sprayed panels, while immersion in seawater for a similar period gave much less attack on the aluminium than on the zinc. Jordan[164] has described the correct procedures for painting sprayed metal coatings, including aluminium, on iron and steel.

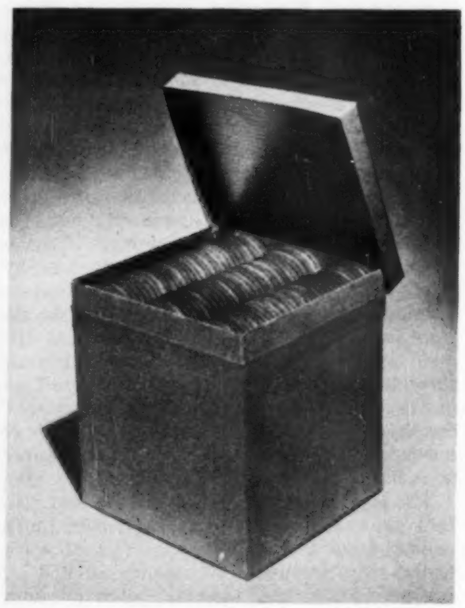
Finally, a rather unusual example of protection. Blum, Lees and Rendle[165] have sheathed the chimney of an oil-fired boiler with aluminium sheet, leaving a ¼-in. radial gap, and the resulting reduction in heat loss raised the temperature of the steel above 121° C. This has prevented corrosion of the steel, and ended the former troublesome emission of smuts.

Applications

The assiduity with which technical journals note, describe and illustrate novel and interesting examples of the use of aluminium and its alloys dooms to failure any attempt at a comprehensive selection. But in 1959 there was no difficulty in choosing the application which



An early stage in the construction of one of the storage tanks for liquid methane at Canvey Island. The picture shows the inner tank of aluminium alloy which in this case was built up simultaneously with the outer tank of mild steel.



One-trip container for 9 lb. of biscuits, made of corrugated board lined with aluminium foil, gives a shelf life of more than three months under severe storage conditions.

excited the most general attention: it was the use of aluminium alloys to make possible the import into this country of liquid methane to fortify our supplies of town's gas. The problems involved in storing a liquid at $-260°$ F. have been set forth,[166] together with their solution by the use of aluminium; the Chairman of the Gas Council[167] has explained the scheme and its future. The aptly-named *Methane Pioneer*,[168] converted for the transport of the liquid gas, has been described. A film made by the Aluminium Development Association[169] summarises the whole project, from the research necessary to ascertain the suitability of welded aluminium alloys for much-reduced temperatures to the final success of the scheme.

Long years of work by the aluminium industry on the development of the application of aluminium to big ships are now bearing fruit. Muckle's long series of researches, sponsored by the Aluminium Development Association since 1942, will be familiar to all naval architects and shipbuilders. Two ships for the Australia run are under construction, the *Oriana*[170, 171] and the *Canberra*;[172] each is over 40,000 tons, and with speeds of 27½ knots these ships will cut a week from the sailing time. Each ship has 1,000 tons of aluminium-magnesium alloy, produced to Lloyds Register requirements, in its superstructure, and the consequent lightening has permitted the inclusion of an extra deck. *Oriana* is stated to be a name given to Elizabeth I; she will be a fit ship for the second Elizabethan age.

In discussing the conversion of a tramp steamer to a luxury liner, Richardson[173] notes that the large, imposing funnel is of aluminium alloys, welded by the manual inert gas metal arc method. Du Cane [74] has described an 80 ft., 37 knot passenger launch with pilot house and passenger deck in aluminium alloy NP5/6; prefabrication was extensive. Considerable savings in draught were achieved by constructing cargo lighters for the Royal Pakistan Navy[175] in aluminium alloy NP5/6, joints being made by rivets in alloy NR5. Personnel boats[176] in aluminium alloy, 52 ft. long, have been made in the U.S.A., the construction being by welding. Sewart and May[177] have described other welded aluminium alloy boats, used by the oil industry in the Gulf area and known as Jo boats. Another application of aluminium in the oil industry is in the cladding of 110 ft. high steel pilings in Lake Maracaibo[178]; aluminium is resistant to the corrosive lake water, which attacks steel rapidly.

Salmon are caught in Alaska from boats known as gillnetters. Ten of these have recently been made of welded aluminium[179] and have a speed of 15 knots compared with the 8 or 9 knots of steel boats, which also require painting, while the aluminium boats are unprotected. New hull forms for ships and boats must be tested; Serbutt[180] has described the new ship-hydrodynamics laboratory opened by the Duke of Edinburgh at Feltham. It has an aluminium roof and roof trusses, and is lined with aluminium-faced insulating panels; the lightning protection is also of aluminium.

Packaging bids fair to be second only to road transport in importance as a market for aluminium. The participation of the metal in two packing exhibitions has been described, one in this country[181] and the other Continental, and aptly named Europak.[182] Mills[183] has surveyed the growth in production between 1954 and 1957 of various types of package and packaging material. Aluminium foil has increased by 50% and collapsible tubes by 40%, but aluminium containers have shown no change. The same author[184] considers the development of aerosols; she sees the future of aluminium in this field as dependent upon ability to lower cost as well as on technical improvement. An automatic line for the production of aerosols[185] in aluminium has been laid down by a well-known manufacturer; impact extrusion, trimming, flanging and finishing are all linked by a conveyor system.

Throughout its history, the hermetically sealed can for food and drink has been the preserve of tinplate, and it is a most tempting market to competitive materials. Some marginal success has been achieved by aluminium in this field, and aluminium beer cans[186] are now in regular production by an Hawaiian brewery. Apart from draught, most beer is supplied in bottles, requiring closures that can keep in the fizz. A crown closure[187] in aluminium–2¼% magnesium alloy is now available, and its advantages have been described. Throw-away containers are always preferable to returnable ones, which must be collected and cleaned; the aluminium foil-lined one-trip biscuit box[188] is therefore the more welcome. Barbecued chicken[189] tastes all the better when packed in a laminated aluminium foil grease resistant bag, and it will keep hot for between one and two hours. A large aluminium collapsible container [190] and its testing [191] have been described. It is of 648 cu. ft. capacity, but weighs only 5 cwt.; all joints are automatically sealed by neoprene weather strips.

In 1959 the Aluminium Development Association held a symposium on the applications of aluminium in building. The event was well attended, and lively discussions followed the presentation of thirteen papers divided between three sessions. An interesting exhibition was also arranged, including, amongst other items, many systems of aluminium curtain walling. The papers and discussions will be published in one volume early in 1960. Laithwaite[192] had set the scene earlier in the year with an assessment of the progress of aluminium as a building material; he notes that the metal has already played a significant part in the development of a new style of architecture. The aluminium materials used in building, the finishes applied to them, and the maintenance necessary have been discussed by Bailey and Porter.[193] Taking one's own medicine is always the ultimate test of faith; the new Aluminium Canada House [94] in Berkeley Square successfully blends a neo-Georgian structure with aluminium windows and doors. There are striking architectural features in aluminium amongst the interior fittings and furnishings.

The new Air Force Academy[195] in Colorado Springs, U.S.A., has attractive and strong chairs made as castings in aluminium alloy. Underfloor heating[196] is rapidly becoming the thing that all the Joneses want and aluminium foil placed under the warming elements improves the efficiency. This form of heating should also help to remove the necessity for fire escapes,[197] which, while they are still needed, are best made of aluminium, as are those at the Royal Gwent Hospital.

Structural applications of aluminium continue. Aluminium bridge construction has been surveyed,[198] from the decking of the Smithfield Street Bridge to the new welded aluminium alloy bridge at Des Moines, Iowa. An American company has designed a prefabricated sectional bridge[199] in aluminium, incorporating triangular beams of sheet stiffened by extrusions riveted on. A covered, thermally insulated foot bridge[200] in aluminium

alloy H30 now connects the head office of the National Provincial Bank, Bishopsgate, with a branch office in Old Broad Street. Yet another footbridge is in South Africa[201]; it is 156 ft. long, and is over the main south coast road about 20 miles from Durban. Rolling heavier slabs of aluminium alloy means more mechanical lifting equipment, and recent installations at Banbury incorporate a 72 ft. box lattice girder and grab[202] made of aluminium alloy sections. At the Brussels Fair in 1958 much aluminium was used in stands and exhibits, but the most impressive feature was the Atomium[203]; its construction has been described, including the cladding of the spheres, using 48 large spherical triangles of aluminium sheet. Also of spherical shape but much greater age is the Time Ball[204] at Greenwich; the current model has been in service since 1919, and is of commercial purity aluminium sheet, about 20 s.w.g. Recent examination showed it to be in excellent condition. An overhead maintenance tower[205] in aluminium alloy may be used indoors and out, without danger of deterioration by corrosion.

Street furniture is becoming a subject in which all are experts, and lamp standards in particular are the butt of criticism. With this in mind, the Aluminium Development Association held in 1959 a competition for the design of aluminium lamp standards of two principal types, which attracted a very large entry and a good deal of interest. The prize-winning entries have been described[206] and also the method of construction[207] of one of them, an ingenious scheme involving the diagonal slitting of special extrusions. Telephone kiosks, like taxis on wet days, are never there when needed, but the new design[208] in aluminium, accepted by the Postmaster-General, perhaps presages an attack on the problem; costs of maintenance will be much reduced. On the M.1, the London to Birmingham motorway, the traffic signs[209] are in aluminium alloy, and are designed to resist gale force winds.

Road transport continues to be the most important field of application of aluminium and its alloys, and so well are they established that novel uses are correspondingly rare. A trailer body[210] for the transport of palletised goods has been described, with a 16-ton capacity and open sides for ease of loading. Much less conventional is the American "Teracruzer," a welded aluminium vehicle[211] for the transportation of guided missiles, over snow, sand, mud or swamps. Mother Shipton foretold carriages without horses; cars without wheels[212] are a future development in the U.S.A., and prototypes that travel on cushions of air have been described which have welded aluminium frames. Transport of coal underground demands mine cars of great strength and resistance to damage. This may be attained by welded aluminium construction, together with important weight saving, as has been described by Flynn.[213] This name is particularly apt in connection with mining in the United States. Three outdoor cinema screens[214] in South Africa have their facings of interlocking aluminium extrusions, etched and anodised to give an ideal projection surface.

A famous British technical journal celebrated in 1959 its Golden Jubilee, by a special issue incorporating articles[215-222] by accepted authorities on the application of non-ferrous metals in various industries. Each author gives many examples of uses of aluminium in his field, and the fifty years under review represent a period of development unparalleled in the history of any other metal.

The Alexandrian desire for fresh worlds to conquer is nowadays becoming more widespread, and has resulted in the presence of new objects in the heavens. Boyd[223] has discussed the construction of one of the Russian Sputniks, which, of course, involves aluminium alloys. According to Hirst,[224] aluminium is also used extensively in the American missile "Vanguard," from which experience is being gained which will be valuable in the construction of future missiles of higher performance. Not all wish to leap with Hotspur to pluck bright honour from the pale-faced moon; some would dive with him to the bottom of the deep, and pluck up drowned honour by the locks. One of these is Piccard, and following his lead an aluminium bathyscaphe[225] has been built for descent to 18,000 ft. Any too-rapid ascent from such a depth might necessitate incarceration in an aluminium recompression chamber[226] to avert attacks of the "bends."

While seeing economic factors as the main force ensuring an expanding future for aluminium in the electrical industry, Thomas[227] discusses also the technical advantages of the metal in this application. A recent advance has been the production of continuously anodised aluminium foil[228] for electrical windings, particularly in magnets and transformers. Lightness combined with close dimensional tolerances make aluminium alloy pressure die castings attractive to the manufacturer of transportable domestic goods; a colour slide projector[229] and a sewing machine[230] have been described. The British land speed record for model cars stands at the astonishing figure of 98·32 m.p.h., and, as with all speed records, was attained with the aid of aluminium alloys. A 5 cc. engine[231] has cylinder head, cylinder and crankcase cast in alloy LM20, the pistons in LM13, and the connecting rod forged in alloy HF12-WP.

The uses of aluminium in the food and chemical industries continue to expand. An installation of aluminium brewing vessels[232] in Canada has been described; they were fabricated by both TIG and MIG welding. Special interest attaches in the rocket age to the production of hydrogen peroxide[233], and its manufacture by the organic process involves much aluminium, which does not catalyse the breakdown of the chemical. High test peroxide is transported in a self-contained unit[234] which has two 500 gallon tanks of aluminium of 99·5% purity.

In 1958 the Institution of Mechanical Engineers and the Aluminium Development Association held a symposium on aluminium pressure vessels, and a most useful volume[235] has now been published, including the papers presented and the discussion on them. This valuable symposium has led to the initiation of work on the preparation of a code of practice for aluminium pressure vessels, and resulted in much interest in these vessels throughout the chemical and oil industries.

In lighter vein, from two points of view, is an article[236] on the use of tubular aluminium in sport. Applications include arrows, javelins, hurdles, jumping laths, billiards cues and relay batons. The advantage is stressed of a material which does not change its properties in the presence of moisture.

Standards

The British Standards Institution has recently devoted a good deal of attention to its standards for aluminium and its alloys as aircraft materials, and a number of revised and new ones have been published. On the wrought side[237] forgings and forging stock in the

aluminium-copper-magnesium-silicon alloy have been separated as L76 and L77 from bars and extruded sections which now form the subject of 2L64 and 2L65. As regards castings, new standards[238] have been published to replace D.T.D.'s 165, 245, 276 and (at last an established material!) 424. D.T.D. 424 has become L79; this designation does not roll off the tongue so readily as the former pair of palindromes, and much metal will probably be poured before every foundryman uses the new letter and numbers. But the recognition of merit, though belated, will be welcomed universally. The document covering inspection and testing of ingots and castings for aircraft has been revised, and appears as 2L101, and nine other material standards re-issued at the same time.[239]

The Ministry of Aviation (*née* Ministry of Supply) now has a specification, D.T.D. 5080,[240] for sheet in an aluminium-magnesium-silicon-manganese alloy, of the type covered in B.S. 1470 by HS30-WP.

Standard aluminium alloy sections for marine purposes are the subject of B.S. 2614,[241] which has been enlarged and re-issued. B.S. 2134[242] covers general equipment and tests for condensers with aluminium electrodes, and also includes a list of standard sizes.

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Direct Reduction of Iron

ENGINEERS and scientists in many countries are interested in the possibilities of alternative methods of producing iron. Several direct reduction techniques have been evolved with varying degrees of success, and research continues on a very extensive scale. While the blast furnace is a remarkably efficient method of making iron, it has certain limitations. Construction involves very heavy capital charges; operation has to be maintained for long campaigns, output levels being variable only within certain limits; furthermore, the process involves the consumption of large quantities of high grade metallurgical coke, expensive in itself and representing additional handling costs.

Direct reduction would appear to go some way towards overcoming these limitations. On the whole, the necessary plant is much less monolithic; operation can be interrupted and re-started with relative ease, introducing a hitherto unattainable degree of flexibility in production planning, and coke of lower quality and/or less volume is employed. Theoretically, at least, the economics of direct reduction would appear to present interesting possibilities.

The international conference on direct reduction organised by the Electrochemical Society of the U.S.A. in Chicago from May 2nd to 5th should therefore arouse considerable interest. Twenty-one papers are scheduled, reviewing progress in Canada, the United States, Great Britain, Sweden, France, Germany and Norway. Further information may be obtained from Dr. R. R. Rogers, Mines Branch, Department of Mines and Technical Surveys, 552 Booth Street, Ottawa, Canada.

NEWS AND ANNOUNCEMENTS

Metal Finishing Conference

THE Annual Conference of the Institute of Metal Finishing will be held at the Grand Hotel, Scarborough, from April 26th to 30th, 1960. In the course of the five technical sessions—two on Wednesday, one on Thursday, and two on Friday—the following fourteen papers will be presented for discussion :—

"Review of Methods for Obtaining Improved Outdoor Corrosion Resistance with Nickel-Chromium Plate," by H. BROWN and D. R. MILLAGE.

"Factors Influencing the Corrosion Resistance of Decorative Plating on Zinc Alloy Diecastings," by O. JONES, V. E. CARTER and J. EDWARDS.

"Sealing Anodic Oxide Films on Aluminium," by G. C. WOOD.

"On the Assessment of Sealing of Anodic Oxide Films on Aluminium," by T. P. HOAR and G. C. WOOD.

"The Growth Habit of Electrodeposited Copper," by G. C. STOREY and S. C. BARNES.

"Throwing Power of Nickel Plating Solutions," by S. A. WATSON.

"Solderability of Some Tin, Tin Alloy and Other Metallic Coatings and the Effect on Them of Storage," by C. J. THWAITES.

"Detection of Zinc Diffusion with Tin Coatings on Brass," by S. C. BRITTON and M. CLARKE.

"Studies on Surface Treatments of Aluminium and Zinc," by D. B. FREEMAN and A. M. TRIGGLE.

"Lacquers for Outdoor Protection of Aluminium," by A. W. BRACE and R. E. M. POLFREMAN.

"Technical Developments in the Application of Coated Steel Sheet," by F. H. SMITH and T. C. TAPP.

"The Economic Advantages of a Sound Painting Scheme," by U. R. EVANS.

"Water-thinned Coatings as Industrial Finishes," by E. L. FARROW.

"The Use of Vinyl Resins in Appliance Finishes," by P. R. DAY.

In addition to the technical sessions, there will be a reception and dance by invitation of the Mayor and Corporation of Scarborough on the Wednesday evening, and the conference dinner and dance on the Friday evening.

Production Exhibition

THE Fourth Production Exhibition will be held in the National Hall, Olympia, London, from April 25th to 30th. This exhibition has a special appeal to management and, in particular, to all those in industry whose task it is to plan for productivity. It draws a large audience of students from technical colleges, and hundreds of firms send organised parties of staff, employees and apprentices. The exhibition is selective, all exhibits being related to the topic of producing goods more cheaply and efficiently, and it provides an effective cross fertilisation of ideas of importance in every industry.

Concession tickets are available for firms to send organised parties at a special rate of 13s. per dozen tickets post free, and personal season tickets are also available. Applications for group visit tickets and season tickets should be made to : The Production Exhibition, 11, Manchester Square, London, W.1 (tel. : HUNter 1951).

During the period of the exhibition, the British Productivity Council will be responsible for organising a conference entitled "Productivity—Men and Methods." This conference will be divided into eight sessions as follows :—

April 25th p.m.—"Computers and Production Control."
April 26th a.m.—"Fitting the Job to the Worker."
April 26th p.m.—"Work Study and Industrial Engineering."
April 27th a.m.—"Variety Reduction."
April 27th p.m.—"Quality Control."
April 28th a.m.—"Communications in Industry."
April 28th p.m.—"Training of Supervisors."
April 29th a.m.—"Organising for Cost Reduction."

Teams of leading specialists will be presenting papers on each of these subjects. Application forms and tickets (price 25s.) can be obtained from the British Productivity Council, 21, Tothill Street, S.W.1.

Refresher Courses

THE first of a number of vacation refresher courses planned by the Metallurgy Department of the Battersea College of Technology will be held from April 5th to 8th, 1960. The title is "The Structure of Metals and Alloys," and the course will be under the direction of Dr. A. P. Miodownik and Dr. J. Mackowiak. Modern metallurgy is being forced to make increasing use of thermodynamics and electron theory in the development of new alloys, and it is becoming apparent that the rate

An artist's impression of Westminster House, the four-storey block of offices in Kew Road, Richmond, which has been built to the special requirements of Stein and Atkinson, Ltd., the designers and builders of furnaces and heat treatment plant, to meet the needs of their expanding business. All engineering and administrative departments are now accommodated in the new premises, which have an attractive all-aluminium and glass frontage.

of progress now necessitates a knowledge of concepts which were previously considered only of academic interest. This course has been designed to bridge the gap between the basic principles of physical metallurgy and those of physical chemistry: it is an attempt to relate many complementary features of these two fields of study. The fee for the course is twelve guineas (inclusive of lunches and refreshments), and enrolment forms and further information may be obtained from the Secretary (Metallurgy Courses), Battersea College of Technology, London, S.W.11.

Internal Defects Conference

An all-day conference on "Internal Defects in Steel and Methods of their Assessments," organised by the West of Scotland Iron and Steel Institute, will be held at 39 Elmbank Crescent, Glasgow, on Friday May 13th, 1960. The following papers have been promised:—

"Some Service Experience and Inspection Considerations," by G. P. Smedley (Lloyd's Register of Shipping, London).

"Methods of Assessing Internal Quality of Steel Tubes and Welds," by J. S. Blair (Stewart and Lloyds, Ltd., Corby).

"The Importance of Internal Quality in Welding," by I. G. Hamilton (Babcock & Wilcox, Ltd., Renfrew).

"The Significance of Defects in Relation to Users, with particular reference to Castings and Forgings," by F. Buckley (English Electric Co., Ltd., Rugby).

"Internal Defects in Plates," by J. E. Roberts (Colvilles, Ltd., Motherwell).

"Internal Defects in Steel Castings," by J. Cameron and J. Courtney (Clyde Alloy Steel Co., Ltd., Motherwell).

"Internal Defects in Large Castings and Large Forgings," by J. M. Mowat and P. Packham (Wm. Beardmore & Co., Ltd., Glasgow).

"Internal Quality of Steel," by V. Scalesi (Societe Italiana Acciaierie Cornigliano, Genoa).

The conference is open to members of any technical society, and the registration fee, including one set of preprints, is £2 10s. (members of the West of Scotland Iron and Steel Institute, £1 15s.). A set of preprints may be obtained by those not attending the conference for £1 1s.

Applications for registration should be made by letter to the Secretary, West of Scotland Iron and Steel Institute, 39 Elmbank Crescent, Glasgow, C.2, not later than May 4th. Contributors to the discussion who desire to use lantern slides should give notice not later than May 7th. A full report of the conference will be published as Vol. 68 of the *Journal of the West of Scotland Iron and Steel Institute*, and will be available to non-members at £2 7s. per copy.

Sheet Shaping and Testing Colloquium

A Colloquium on "The Shaping of Sheet Metal and the Testing of Sheet," organised by the International Deep Drawing Research Group and the Société Française de Métallurgie, will be held in Paris from May 23rd to 25th, 1960. Some thirty papers, in English, French or German, will be presented for discussion, the topics to be covered being grouped under the following headings: anisotropy, fundamental studies, the Swift cupping test, cup forming tests, the Erichsen test, miscellaneous testing procedures, miscellaneous studies, and new techniques.

There will be a registration fee of 60 new francs (approx. £4 7s. 6d.) to cover Secretariat expenses, the printing of the papers, and the reception charge. The cost of a set of papers to anyone not attending the colloquium will be 30 new francs (approximately £2 4s. 0d.). Full particulars may be obtained from the Secretariat of the Société Française de Métallurgie, 25 Rue de Clichy, Paris, 9ème. The closing date for receipt of registrations is April 20th.

Wernher Memorial Lecture

The Fifth Sir Julius Wernher Memorial Lecture of the Institution of Mining and Metallurgy will be given by Dr. I. W. Wark in the Assembly Hall, Church House, Westminster on Wednesday, April 6th, 1960, at 5 p.m. Dr. Wark, who is Chief of the Division of Industrial Chemistry, Commonwealth Scientific and Industrial Research Organisation, Melbourne, will take as his subject "The Exploitation of Minerals for Mankind."

Personal News

Mr. J. Mackenzie-Mair has been appointed to the board of Steel, Peech and Tozer, a branch of The United Steel Cos. Ltd., and assumes the title of director and commercial manager. Mr. W. T. Vizer Harmer remains a full-time director of Steel, Peech and Tozer.

Mr. J. Baxter has been appointed field sales manager for the Scottish branch of Griffin and George, Ltd.

Sir Alexander Fleck, K.B.E., F.R.S., who retired from the chairmanship of Imperial Chemical Industries Ltd., at the end of February, has been appointed president of the Society of Chemical Industry for 1960–61 in succession to M. E. J. Solvay.

Mr. W. C. Bolenius, executive vice-president of American Telephone and Telegraph Co., New York, has been elected a director of The International Nickel Co. of Canada, Ltd.

Mr. G. F. Waddington, export manager, Wolf Electric Tools, Ltd., is on a three months' visit to Australia, where his headquarters are at Wolf Sales Pty., Ltd., Arthur Street, Homebush, Sydney.

Obituary

We regret to record the death on February 26th, 1960 of Mr. G. R. Woodward, manager of the information department of the British Cast Iron Research Association. Mr. Woodward joined the Association's staff in October 1934 as librarian. In 1946 he was appointed manager of the information department of the Association, being responsible for all publications, conferences and exhibitions. Under Mr. Woodward's guidance, the Association's publications achieved an international standing, and their high standard of accuracy was largely due to his editing. One of the most recent tasks upon which he was engaged was the production of the Association's *Journal and Bulletin and Foundry Abstracts* in a completely new form. This appeared in January of this year while Mr. Woodward was in hospital.

Mr. Woodward was well known to many members of the ironfounding industry, particularly to those attending exhibitions and conferences organised by the British Cast Iron Research Association. He was a man of wide interests and showed unfailing courtesy and good humour in the most trying circumstances.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Single-Stage Regulators

New single-stage oxygen and acetylene regulators—the S.O.R.1 and S.A.R.1—which are manufactured by British Oxygen Gases, Ltd., have been subjected to rigorous field trials at home and in five overseas countries. They complement the company's P.R.1 propane regulator, which has been on the market since January, 1958. Designed for rough service conditions where very fine pressure adjustment is not required, these inexpensive regulators weigh only three pounds in spite of their robust construction. They are intended for use in heating and cutting applications, and are considered particularly suitable for general cutting and "on-site" work.

The pressure gauges are of the small dial type (1⅞ in. in diameter), and give a pressure range of 0–3,000 lb./sq. in. oxygen and 0–600 lb./sq. in. acetylene. Their strength is increased by the use of ¼ in. national pipe taper thread which gives an approximate diameter of ½ in. A feature of the regulators is that all the joints are solderless. The range of nominal outlet pressures is indicated by an embossed scale on the top of the spring cap in association with a pointer contained on the pressure adjusting knob. In the case of the S.O.R.1 this reads 0–120 lb./sq. in. and in that of the S.A.R.1 0–15 lb./sq. in. Single-stage regulators are, in general, prone to freezing at high flow rates, and every care has been taken to avoid such an occurrence with this new design.

British Oxygen Gases, Ltd., Spencer House, St. James's, London, S.W.1.

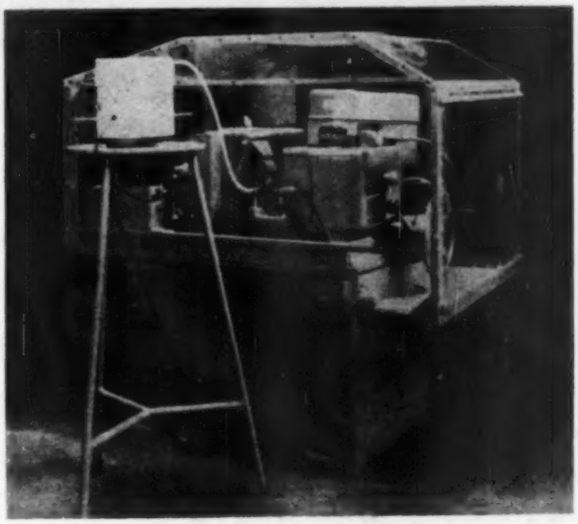
Packaged Oil-Gas Plants

The Incandescent Heat Co., Ltd., report their development of a new process for the gasification of petroleum oil: the process is continuous and does not employ catalysts. Cracking heat is supplied by burning oil and waste products in a compact and simple furnace setting. The oil to be gasified is injected together with steam into a system which is specially designed to enable a uniform and precise control of cracking temperatures to be exercised. By these means the production of unwanted by-products (particularly carbon and tarry condensates) can be kept to a minimum; more particularly the calorific value of the gas produced can be varied continuously in the range 500 to over 1,200 B.T.U./cu. ft. The gas is interchangeable with natural gas or coal gas of similar calorific value, and results obtained with a heavy distillate oil indicate that this system can be operated economically over a wide range of throughputs.

The Incandescent Heat Co., Ltd., Smethwick, Birmingham.

Centreless Grinding Dust Control

The grinding of certain of the materials used in nuclear engineering, apart altogether from any question of radioactivity, necessitates certain precautions on account of the toxic character of the dust produced. The usual



Grinder with plastic hood in place

methods of dust extraction cannot, of course, be 100% effective when applied to a centreless grinder, due to the conditions imposed by the design of the machine, but the illustration shows one of the latest Wickman-Scrivener model 0 centreless grinding machines with special equipment designed by Arthur Scrivener, Ltd., for this new and rapidly developing field of work. The machine, when photographed, was set up for grinding uranium oxide slugs, and it will be noticed that the equipment includes a transparent plastic hood with suitable doors to give access to the machine controls when this is necessary, the work being fed to the grinding throat of the machine from the small vibratory hopper.

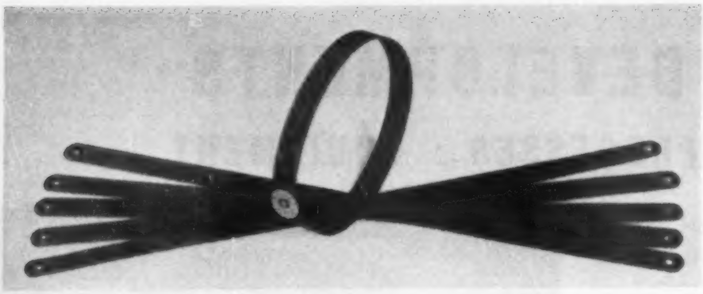
The machine shown has a grinding wheel 12 in. (305 mm.) diameter and a control wheel 7 in. (178 mm.) diameter, both 3 in. (76 mm.) wide, the main driving motor being 5 h.p. (3·75 kW.). On small cylindrical work of this description, it is capable of a production of several thousand pieces per hour, a result impossible of achievement by any other method.

Arthur Scrivener, Ltd., Tyburn Road, Birmingham 24.

Flexible High-Speed Hacksaw Blades

In order to simplify administration and achieve better distribution, all tools manufactured by the Darwin's Group will be concentrated into one section, which will be known as the Darwins Tool Division (J. Stead & Co., Ltd., Manor Works, Sheffield, 2.). In addition, Steadfast will be the brand name for all tools made by the Darwins Tool Division.

The first of the Division's new products is a range of flexible high speed steel hacksaw blades. These blades are hardened on the teeth only, and give a cutting



A group of Steadfast flexible high-speed steel hacksaw blades

performance equal to that of any normal high speed steel hacksaw blade. By virtue of the fact that they are hardened on the teeth only, these blades are quite flexible, a feature which helps to eliminate breakage of blades by unskilled labour.

J. Stead & Co., Ltd., Manor Works, Sheffield, 2.

Seal for Hot Processing Baths

A NEW treatment which provides a protective chemical blanket for hot immersion processing baths has been introduced by the Metal Finishing Division of the Pyrene Co., Ltd. Known as Heat-Lok, the treatment consists of two integral components, namely the Heat-Lok sealant, forming a protective blanket on the surface of the processing bath, and the Heat-Lok additive, which is a surface activating agent in the processing solution itself. It is claimed that, far from having a harmful effect on the coating characteristics of the processing solution, Heat-Lok frequently increases the efficiency of the process, tending to produce more complete and uniform coatings. The ½ in. chemical blanket practically eliminates surface evaporation and greatly reduces warm-up time by sealing in the heat. It also blankets all steam vapours, fumes and heat, containing them within the bath itself, and thereby improving working conditions. With savings in B.Th.U.'s there is less demand for heat and, consequently, maintenance on heating elements is correspondingly reduced. Furthermore, exhaust system requirements can be cut to the minimum, if not completely eliminated, and, since corrosive elements are blanketed and held within the bath proper, corrosion of nearby equipment is minimised.

The Pyrene Co., Ltd., Metal Finishing Division, Great West Road, Brentford, Middlesex.

Polishing and Deburring

ALTHOUGH the deburring and polishing of comparatively small parts is still carried out by hand, there is a growing use of polishing barrels or drums. This technique has changed in detail since it was first introduced, and a recent development of the Hans Getiker Company is claimed to avoid some of the difficulties arising with earlier methods.

Rusting occurred when the parts were rotated in a drum with water and sand, and the process was too slow. Later, when special chemicals were added, there was a possibility of explosion when chemicals unsuitable for the metal concerned were used.

The new Swiss technique is known as the Rotol method, and uses extremely hard mineral grains together with especially developed chemicals in a rotating drum. The polishing grains normally range in size from 2 mm. to 40 mm., but for treating metal parts of complex shape grains smaller than 2 mm. are used as an additive. For the complete treatment of all kinds of metal parts, only two chemicals are used, and they are not easily confused. These chemicals serve for degreasing, derusting, deburring and polishing, and an additional chemical will protect parts from rusting after treatment.

The drums used for the Rotol process are lined with soft rubber, and for safety reasons the covers shut hermetically and can be bolted; the electrical equipment is thoroughly insulated; and safety valves are fitted. A time-switch enables the process to be carried on night and day without any further personal supervision.

Hans Getiker, Metallwaren und Apparatefabrik, Horgen, Switzerland.

Reinforcing Concrete Floors

A NEW product called Hexweb has been introduced by Causeway Reinforcement, Ltd., for reinforcing concrete floors. When such floors are subjected to constant wear from heavy-duty trucking and live loads, it is a common occurrence for them to fracture. Various methods have been tried to prevent them from breaking up, the most common being to localise the shock by dividing the floors into small rectangular areas by joints. This method, however, has the disadvantage that the edges of the slabs tend to spall, and a further difficulty is presented when heavy vehicles with small wheels pass continually over the division joints.

Hexweb is a webbed chilled cast-iron floor grid designed and chemically toughened to meet the load demands of the heavier industrial floors. Each Hexweb grid is hexagonal in shape, and has a mean diameter of 11½ in. The grids are laid in a concrete wet mix and infilled with a stiff infiller. This combination provides, it is claimed, a flooring of exceptionally long life which will resist wear under all rolling and shock loads; additionally it offers resistance to corrosion and is anti-skid. Individual grids can be removed from the floor without disturbing the adjacent grids. By their design they meet situations where trucking in all directions takes place, since, unlike square plates, they present no continuous leading edge against which the wheels can strike and cause fracture. The natural honeycomb expansion joints of Hexweb present, it is claimed, the only real answer to the problem of cracking. The unique three point ground contact prevents voids when infilling; it can be laid without breaking up existing surfaces, and the graduated hexagon bars make possible a concrete underfloor with added sheer lines.

Causeway Reinforcement, Ltd., 11a, Albermarle Street, London, W.1.

CURRENT LITERATURE

Book Notices

RESEARCH HIGHLIGHTS OF THE NATIONAL BUREAU OF STANDARDS

Annual Report 1959, National Bureau of Standards Miscellaneous Publication 229, 169 pp. Copies may be ordered from Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (55 cents plus 25% postage overseas).

THIS illustrated report brings together the most important developments in the research programme of the Bureau during 1959. It describes a wide range of scientific studies, laboratory experiments, and instrumentation developments arising from the Bureau's responsibility for leadership in the science of measurement. Much of the material is concerned with the new technology of the space age. Progress is reported in extending the calibration range of optical pyrometers from 2,400° to 3,800° C.; the development of a high-current arc as a source of controlled temperatures; and the design of a special type of high-temperature resistance thermometer for interpolating between fixed points on the International Temperature Scale. To obtain data for the ultimate establishment of additional fixed points on the pressure scale, equipment was developed for studying the behaviour of materials at pressures up to 1,500,000 lb. per sq. in.

Other research reported includes the refinement of atomic standards of length and frequency, confirmation of the Rydberg constant, establishment of a vibration pickup calibration service, and special measurements of the heat conductivity of explosives and solid propellants. Special efforts are reported on the properties of materials at high temperatures. Some of these studies deal with solid state reactions in high-temperature alloys, refractory coatings for aircraft and missiles, and new cements for high-temperature strain gauges. Radio research includes ionospheric soundings, development of a communications system which reflects messages off meteor trails, refraction of radio waves in the earth's atmosphere, and many other topics. The Report also summarizes the Bureau's calibration, testing and standard samples programmes, publications programme, and co-operative research with industry. A brief summary of some of the programmes planned for the coming year is included.

KEMPE'S ENGINEER'S YEAR BOOK FOR 1960

Volumes I and II in case. 3,000 pp., Crown 8vo., numerous illustrations and tables, 120 pp. index. Morgan Brothers (Publishers), Ltd., 22 Essex Street, Strand, London, W.C.2. 87s. 6d. and 2s. 6d. postage.

WITH a year book whose cost is such that for many people it is not an annual "buy," there must be a temptation to rely on "the mixture as before." As usual, the temptation has been resisted by the publishers of Kempe's, each chapter having received the close attention of an authority in the particular field, to ensure that its contents are kept up to date. This is a vital requirement in a work of this nature at any time, but particularly so at present, in view of the rapid developments which are taking place in various fields of engineering. As a consequence of this revision there are more than 120 pages of new tables and text, completely new sections dealing with "Electronic Engineering"; "Nuclear Power" (replacing the chapter on "Atomic Power"); "Prestressed Concrete"; "Diesel Locomotives and Railcars"; "Railway Brakes"; "Railway Signalling"; and "Naval Architecture." Valuable additions have also been made to nine other chapters, and numerous alterations and additions due to the issue of new and revised British Standards are included. Among the additions to existing chapters are items dealing with high temperature steels, cutting tool coolants, ceramic tipped cutting tools, tube bending machines, machinery skids, dolly trucks, high pressure flow meters, fatigue testing machines, the base exchange process of water softening, N.C.B. coal classification tables, boilers and boiler furnaces, and performance of refrigerants.

It is one thing having available the vast amount of information contained in these two volumes, it is another being able to find the items one wants. There should be no cause for complaint on this score, as the 120 page index, with its 17,000 entries, makes reference quick and easy.

Trade Publications

THE section covering literature on heat- and corrosion-resisting materials forms an interesting feature of the December, 1959, issue of *The Nickel Bulletin*, and of particular interest are the thirty-four abstracts indicating the scope of papers originally presented at a Symposium on High-Temperature Materials sponsored by the American Institute of Mining, Metallurgical and Petroleum Engineers and now published in book form. The remainder of the items in this section summarise the salient findings of work carried out to evaluate the corrosion-resistance, high-temperature properties or weldability of various nickel-containing alloys and steels. In the plating section, references to the modified B.N.F. plating gauge supplement an abstract drawing attention to the requirements of the recently revised British Standard on electrodeposited nickel/chromium coatings, while other items give details of investigations concerned with evaluation of atmospheric corrosion-resistance, the anodic behaviour of various grades of electrolytic nickel, and the influence of plating variables on the properties of nickel electrodeposits. The other abstracts contained in the issue provide an apt illustration of the wide range of industries in which nickel plays an important role.

MIDLAND SILICONES, LTD., have recently published a well-illustrated technical booklet describing the engineering applications of their range of silicone fluids, including damping devices, liquid springs, fluid couplings, and hydraulic power transmission units. The booklet "Engineering Guide to MS Silicone Fluids," emphasises that silicone fluids are outstanding for their exceptional thermal stability and resistance to oxidation. All these fluids show a remarkably small change in viscosity with temperature and resist breakdown due to shear. They are water repellent and retain good dielectric characteristics over a wide range of temperatures and frequencies. Other desirable properties include low volatility, low

freezing point, high flash point, and incompatility with organic oils and polymers. Copies may be obtained from Midland Silicones, Ltd., 68, Knightsbridge, London, S.W.1.

"It's not an accident . . ." is the intriguing wording on the front of a new folder which recently came into our hands. On opening it the sentence continued " . . . when the quality of your product leads the field." The rest of the folder details the care and attention devoted to customers' needs in the production of millivoltmeters by Honeywell Controls, Ltd. The first stage at which this shows is in the comprehensive nature of the range, there being, for instance, 150 standard ranges and scales on the indicating instrument to meet individual requirements. The controller, too, offers a choice of shape and a range of control types, and a full range of accessories is available. The second section deals with attention to details of design and construction that make for accuracy and reliability. Finally, reference is made to the after-sales service facilities available to customers.

Since its foundation in 1914, The Stourbridge Refractories Co., Ltd.,—manufacturer of high-grade firebricks, blocks and tiles for horizontal, vertical and segmental retorts, regenerators, coke ovens, generator and producer linings, water gas plant and furnaces in general—has concentrated on the production of refractories which conform to the stringent specifications issued by the Institution of Gas Engineers and, more recently, by the Joint Committee of the Gas Council and the Gas and Coking Industries. A booklet recently published by the company describes briefly the properties, and some of the applications, of SARCO refractory products, which besides bricks and shapes, include a series of high-grade refractory cements, each with its own special properties to meet a particular use.

K. & L. Steelfounders and Engineers, Ltd., of Letchworth, have recently issued a pocket edition "K. & L. Standard Steels for General Purposes" in which the steels made by the company are classified in five main groups: cast carbon steel for magnetic applications; cast carbon steel for general engineering purposes; cast low alloy steel for general engineering purposes; cast low alloy steel for elevated and sub-zero temperature service; and cast austenitic manganese steel. Details given include equivalent British and U.S. Standards, chemical composition, mechanical properties, and, where appropriate, magnetic properties. A wall chart ($17\frac{3}{4} \times 13\frac{3}{4}$ in.) is also available covering these steels.

As usual, the January issue of the *Craven Machine Tool Gazette* features a description of a number of recently constructed machines, which include three of special interest to steel works. They are a bar skimming machine, capable of dealing at high speeds with either mild steel or high tensile steel bars from $3\frac{1}{2}$ in. to $8\frac{1}{2}$ in. in diameter; an ingot planer; and an ingot slicing machine which will accommodate ingots from $10\frac{1}{2}$ in. to 21 in. in diameter, and from 6 ft. 5 in. to 9 ft. in overall length, and can make ten parting cuts simultaneously.

A new leaflet—Publication 501—has been issued by the standard furnace division of A.E.I.-Birlec, Ltd. This deals with general purposes furnaces of the box type which are made in two ranges. The type G.P. 1,000 are designed for use at temperatures up to 1,000° C. and the type G.P. 1400 for temperatures up to 1,400° C. They are batch type units with a horizontal rectangular chamber, fitted at one end with a refractory-faced door which is raised and lowered by a handwheel. The low voltage heating elements—nickel-chromium alloy and silicon carbide rods in the G.P. 1000 and G.P. 1400, respectively—are isolated on opening the door. Automatic heat-fuse protection is provided to prevent dangerous overheating.

A new Mond publication, "The Case-Hardening of Nickel Alloy Steels," explains, with the assistance of numerous tables and diagrams, the object of case-hardening steel components and the three processes employed—pack carburizing, gas carburizing and liquid carburizing. The heat treatment after carburizing is also dealt with in detail, and the publication continues with information on core properties, fatigue and carburizing defects and their elimination. The appendix provides full information on the influence of temperature and time of carburizing on case depth, which will be valued by those engaged in the heat treatment of steels. This publication may be obtained free on request from The Mond Nickel Co., Ltd., Publicity Department.

Each year over four hundred people in this country die as a result of fires, and it is estimated that the cost in money of this menace is over £26 million—equivalent to 20,000 men permanently employed in restoring the ravages of fire. First-aid in firefighting can be an important factor in reducing these figures, and Nu-Swift, Ltd., have recently issued a comprehensive catalogue, in which a discussion of the various types of fire risk is followed by particulars of the various types of extinguisher in the Nu-Swift range.

Books Received

"Process Integration and Instrumentation." Electricity and Productivity Series No. 8. 204 pp. inc. index and numerous illustrations. London, 1959. Electrical Development Association. 8s. 6d.; by post 9s.

The Ironfoundry Handbook. 1st Edition. 391 pp. London, 1959. The Standard Catalogue Co., Ltd. 42s. for a single copy; 35s. each for two or more copies.

"The Corrosion and Oxidation of Metals: Scientific Principles and Practical Applications." By U. R. Evans, 1,094 pp. inc. author and subject indexes. London, 1960. Edward Arnold (Publishers), Ltd. 140s. net.

"Handbook of Electrochemical Constants." Compiled by R. Parsons. 110 pp. London, 1959. Butterworths Scientific Publications. 30s. By post 10d. extra.

"Annotated Equilibrium Diagrams of Some Aluminium Alloy Systems." By H. W. L. Phillips. Institute of Metals Monograph and Report Series No. 25. 86 pp. London, 1959. The Institute of Metals. 30s. ($4·65).

"Vocabulaire Technique." English-French/French-English. By F. Cusset. (Electricité, Mécanique, Mines, Sciences, Métallurgie). 663 pp. Paris, 1959. Editions Berger-Levrault. NF16.

"Problems of Metallography and the Physics of Metals." By B. Ya. Lyubov, Editor. Translated from Russian. 476 pp. New York and London, 1959. Consultants Bureau, Inc., and Chapman & Hall, Ltd. 76s. net.


Heat treatment
Cucumbers grow firm and ripe in the controlled heat of the greenhouse — and metal parts receive the best heat treatment in 'Cassel' salt baths.
With salt baths as with greenhouses, what counts is experience. The 'Cassel' Heat Treatment Service has long experience in carburising, heat treatment, tempering, martempering and austempering.
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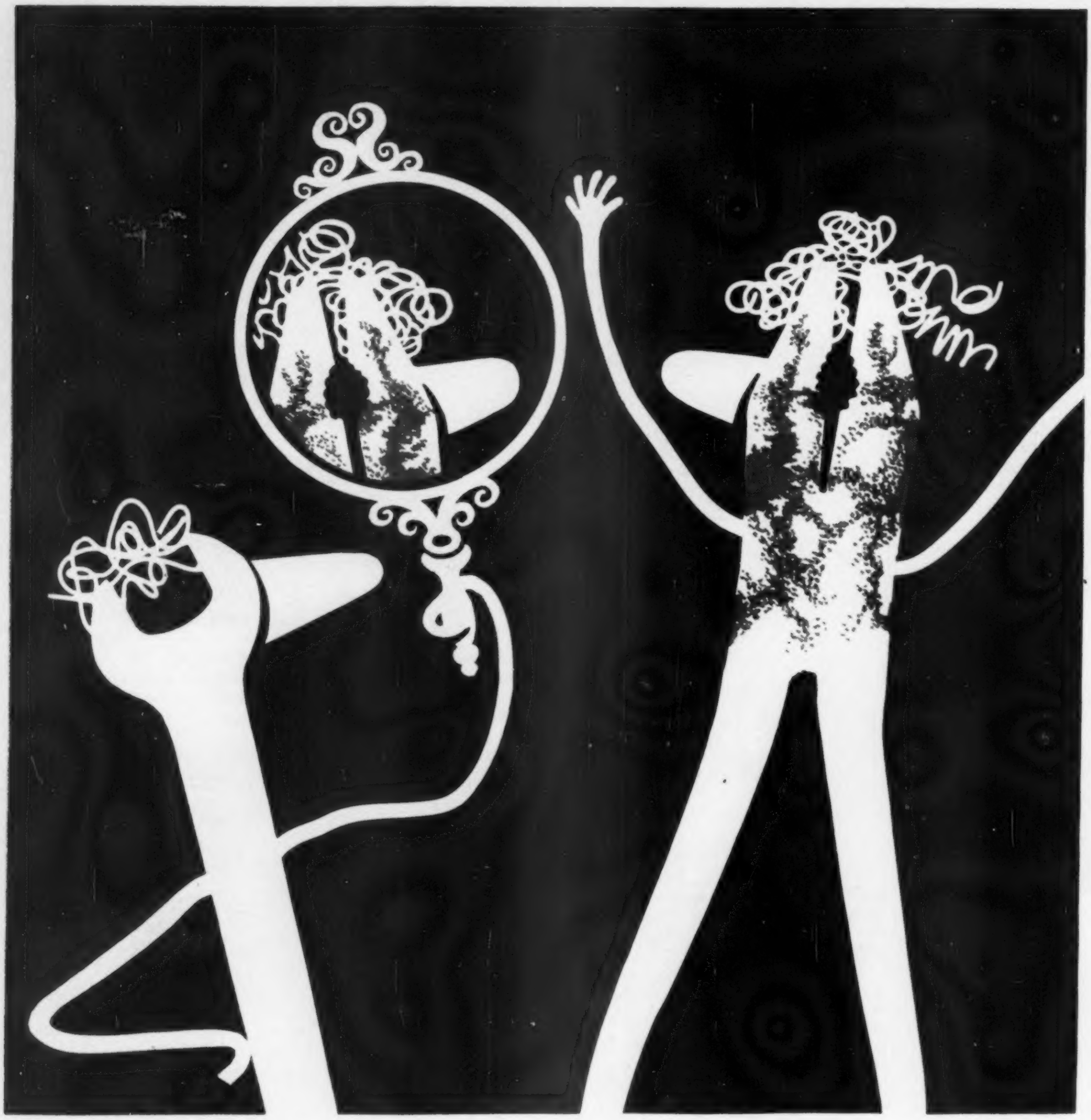
Imperial Chemical Industries Ltd.,
London, S.W.1.



LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

MARCH, 1960. Vol. LXI, No. 365

A Simple Electropolishing Cell

By M. K. Asundi and K. Tangri*

Metallurgy Division, Atomic Energy Establishment, Trombay, India

A description is given of an electropolishing unit constructed in polythene and having an electrolyte recirculation pump incorporated. The system is highly resistant to corrosive electrolytes and only a relatively small quantity of solution is required. Change-over of cathodes and electrolytes is easily accomplished.

ELECTROLYTIC polishing and etching have been increasingly used for the preparation of metallographic specimens because of the ease and rapidity with which they reveal the true structure. In certain cases it is the only possible method at present known for revealing the full details of the structure. It is also claimed that, in studying structures by means of polarised light, better results are obtained with electropolished specimens.

As may be seen from published literature,[1-6] numerous designs of electropolishing cell have been developed, and some units are commercially available. Disadvantages of some of these developments include: use of large quantities of electrolyte; inadequate movement of the electrolyte; lack of corrosion resistance to all the electrolytes likely to be encountered; and use of a fixed cathode. The cell described here is claimed to be free from such drawbacks. It is constructed in polythene and has given satisfactory results with a wide variety of metals and alloys.

Details of Construction

A drawing of the electropolisher is given in Fig. 1. It comprises a polishing cell (7), a storage tank (2) for the electrolyte, and a recirculating system—all in polythene. The cell is a cylindrical box having a watertight lid. A seat is made in the centre of the lid to accommodate the mounted specimen (5). The cathode plate is placed at the bottom of the cell, parallel to the surface of the specimen, and the connection (6) to the cathode plate passes through the lid. The distance between the specimen (anode) and the cathode is 2 cm., and the area of the cathode is almost twenty times that of the specimen.

The cell is supplied with electrolyte from the tank by means of a pump, which consists of an impeller (3) (a simple four-vaned stirrer) enclosed in a cylindrical space formed when the base (4) fits into the lower part of the tank body. The impeller is run by a small ($\frac{1}{35}$ h.p.) variable speed motor (1).

The pump and the cell are connected by a flexible polythene tube (8). About 150 ml. of electrolyte is required for smooth operation of the cell, but larger quantities can be handled, if necessary, by increasing the size of the storage tank. The general flow of the electrolyte is indicated by arrows in Fig. 1: the electrolyte leaves the pump tangentially and also enters the cell tangentially, thus incorporating in the cell the idea of the swirling electrolyte, which is beneficial in facilitating removal of the adhering gas layer or thin film of oxide formed on the surface of the specimen. The rate of flow of the electrolyte can be adjusted to any desired value by controlling the motor speed: normally recirculation occurs five times a minute.

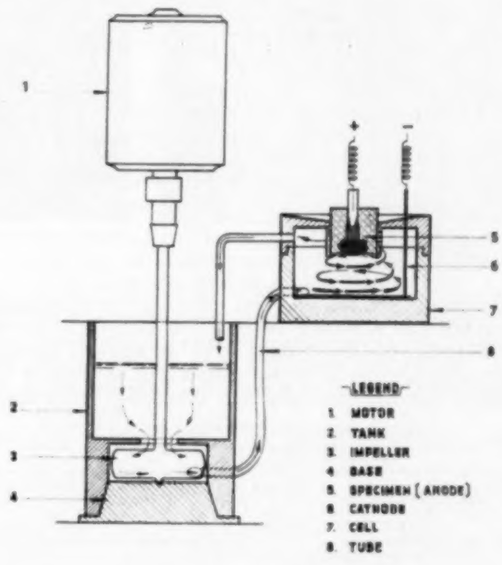


Fig. 1—Diagram of the electropolisher (scale is in cm.).

Cathodes can easily be changed by removing the lid and detaching the plate. Alternatively, cells, or even cell lids, with fixed cathodes can be kept in readiness for a quick change. The tank can be drained by disconnecting

* Mr. Tangri is now at the Fulmer Research Institute.

(a) (b) (c)

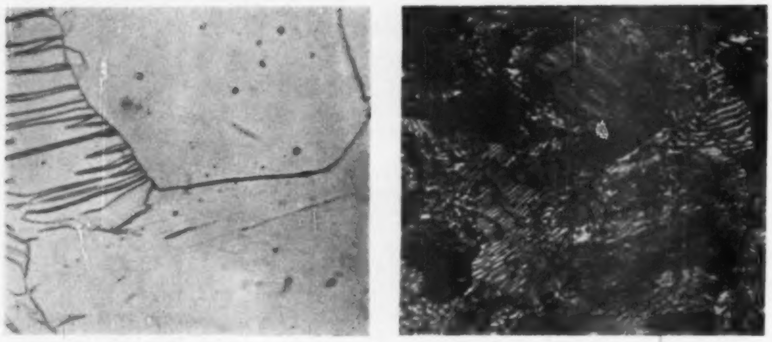


Fig. 2—Photomicrographs of electropolished specimens:
(a) cast uranium, polarised light, × 120;
(b) aluminium, polarised light, × 90;
(c) zinc, × 90;
(d) magnesium, × 500;
(e) eutectoid steel, × 500.

(d) (e)

the tube at the cell end and allowing the electrolyte to flow out into a storage bottle. The pump may be operated during the draining to drive out most of the liquid. The change-over from one electrolyte to another takes only a few minutes, and the ease with which cathode and electrolyte can be changed facilitates the use of the cell for polishing a range of materials. Table I lists the electrolytes used for different alloys, and typical photomicrographs of electropolished specimens are presented in Fig. 2.

TABLE I—ELECTROLYTES FOR VARIOUS METALS

Electrolyte			Metal or Alloy
(1)	Nitric acid (conc.) Methyl alcohol	1 part 2 parts	Aluminium, aluminium-silicon (10%), and aluminium-uranium (1·3, 3·2 and 21%).
(2)	Orthophosphoric acid Distilled water	4 parts 6 parts	Copper and α-β brass.
(3)	Orthophosphoric acid Distilled water	45 parts 55 parts	Cadmium.
(4)	Orthophosphoric acid Ethyl alcohol	3 parts 5 parts	Magnesium, nickel, cupro-nickel, and zinc.
(5)	Orthophosphoric acid		Aluminium bronze
(6)	Chromic acid Glacial acetic acid Water	25 g. 133 ml. 7 ml.	Steel (plain carbon)
(7)	Perchloric acid Ethyl alcohol	6 parts 94 parts	Stainless steel
(8)	Ethylene glycol Orthophosphoric acid Ethyl alcohol	5 parts 5 parts 8 parts	Uranium and uranium-zirconium (5%)
(9)	Glacial acetic acid Chromium trioxide Distilled water	400 ml. 85 g. 100 ml.	Uranium
(10)	Orthophosphoric acid Sulphuric acid (conc.) Distilled water	1 part 2 parts 2 parts	Uranium
(11)	Pyrophosphoric acid Chromium trioxide Orthophosphoric acid Sulphuric acid (conc.) Distilled water	10 g. 10 g. 40 ml. 100 ml. 200 ml.	Uranium

Conclusion

A simple electropolisher suitable for a wide variety of metals has been designed and constructed. The special advantages claimed for the unit are:

(1) Only a small quantity of electrolyte is required (less than one-third of that often specified).
(2) Change-over of cathodes and electrolytes is easily accomplished.
(3) The system is highly resistant to corrosive electrolytes.
(4) The unit is simple in construction and operation and yet it has given satisfactory results with a number of pure metals and their alloys.

Acknowledgments

The authors gratefully acknowledge the willing cooperation of Mr. D. D. Mankame and the keen interest evinced by Dr. Brahm Prakash during the progress of this work. Thanks are also due to the Atomic Energy Establishment authorities for permission to publish this note.

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Metallic Thermocouples for the Measurement of Temperatures above 1,600° C.

THE use of platinum versus platinum-rhodium alloy thermocouples has been long established as the most reliable and satisfactory method for the continuous measurement of elevated temperatures in the range up to 1,600° C. The accuracy and reproducibility of the measurements obtained from these couples is vouched for by the use of the platinum versus 90% platinum-10% rhodium couple to define the International Temperrature Scale in the range from 630·5° C. to 1,063° C.

The development of increasingly refractory materials of construction has permitted operation at temperatures greater than were previously practicable and this has, in turn, created a demand for means of continuous and accurate measurement of temperatures in ranges above that of the conventional platinum and platinum-rhodium thermocouples.

Methods available for the measurement of such elevated temperatures, and based upon the measurement of radiation arising from the hot body, are subject to errors arising from external sources and from uncertainties in the emissivity of the surface being observed. The use of metallic thermocouples eliminates these sources of error, as the thermal electromotive force affords a direct measurement of the temperature at the hot junction of the couple and is not affected by environmental factors. In addition, the thermal electromotive force is readily subject to instrumentation, thereby facilitating the introduction of automatic control installations. Further advantages of the metallic thermocouple as a temperature sensing device lie in its comparatively robust nature, leading to ease of assembly and maintenance, and its small diameter and relative flexibility, which facilitate measurements in otherwise inaccessible locations.

Development work in the field of high temperature thermocouple pyrometry has been concentrated in two main fields, based, respectively, on the higher melting point metals of the platinum group and on the highly refractory base metals of groups V and VI of the periodic table.

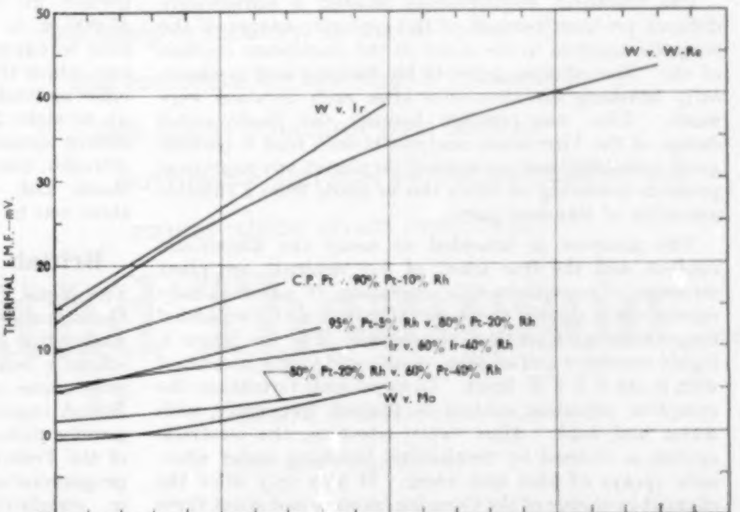
Feussner's introduction of the iridium versus 40% iridium-60% rhodium thermocouple, in 1933, extended the range of thermo-electric pyrometry to 2,000° C. Subsequent work has shown that the iridium versus 60% iridium-40% rhodium couple provides similar thermo-electric characteristics to the original Feussner couple but with greater stability of calibration, and this couple still finds wide application. Many other combinations of metals of the platinum group, and their alloys, have been investigated, but none has been found to be more satisfactory than the iridium versus iridium-rhodium alloy couple.

Amongst the refractory base metals investigated, work has been discontinued on tantalum and niobium, owing to their highly reactive nature at the temperatures of operation. The tungsten versus molybdenum couple has found a limited application but suffers from the following disadvantages :

(1) The thermo-electric output is low and undergoes an inversion of polarity at approximately 1,250° C., as shown in the accompanying graph.

(2) The thermo-electric characteristics of the couple are very sensitive to minor variations in the methods of fabrication of the refractory components, and reproducibility from batch to batch is correspondingly poor.

(3) Both thermoelements are readily oxidisable, neces-



Summary of the thermo-electric characteristics of some high temperature thermocouples.

sitating the provision of a protective atmosphere during operation.

The iridium versus tungsten couple provides a high thermo-electric output with a virtually linear calibration at the temperature of operation. Batch to batch reproducibility of this couple, which may be used for the measurement of temperatures up to 2,300° C., is superior to that of the tungsten versus molybdenum couple, but it is still necessary to provide a protective atmosphere to prevent oxidation of the tungsten member at operating temperatures.

Extensive research in the Rugby Research Laboratories of the A.E.I. Lamp and Lighting Co., Ltd., has led to the development of a tungsten versus tungsten-rhenium alloy thermocouple, now marketed exclusively by Engelhard Industries, Ltd. This couple provides a high thermo-electric output, of the same order as that of the tungsten versus iridium couple, and represents a major step forward in extending the range of high temperature thermocouple pyrometry to temperatures of the order of 2,800° C.

Some details of the high temperature thermocouples now available from Engelhard Industries, Ltd., are summarised below, and in the graph. Whilst each of these couples offers unique advantages in certain fields of application it can be seen that there is a certain amount of overlap in the useful ranges of the individual couples.

The Iridium versus 60% Iridium-40% Rhodium Thermocouple

This couple is suitable for use under oxidising conditions for the measurement of temperatures up to 2,000° C. The couple may also be used in a neutral atmosphere but becomes embrittled if exposed to reducing conditions for lengthy periods. The temperature/electromotive force relationship, in the range of application, is very nearly linear and the couple possesses exceptional stability of calibration.

The Iridium versus Tungsten Thermocouple

This couple may be used in a neutral protective atmosphere, preferably of argon or helium, for the measurement of temperatures up to 2,300° C. The tungsten member renders the couple unsuitable for use under oxidising conditions. Satisfactory operation may be maintained for short periods under reducing conditions, but prolonged exposure to such environments will lead to mechanical failure arising from progressive embrittlement of the iridium member. The temperature/electromotive force relationship in the range of application is very nearly linear, and this couple provides the highest output of any couple in the high temperature range.

The Tungsten versus Tungsten-Rhenium Thermocouple

The couple is suitable for use under neutral or reducing conditions for the measurement of temperatures up to 2,800° C. The temperature/electromotive force relationship is not linear, but the couple provides a high output second only to that of the iridium-tungsten couple in the relevant temperature range.

All these couples are normally supplied in the form of wire at 0·020 in. diameter. Other sizes may be manufactured to special order, if required.

Analytical Equipment for Canada

The first Canadian order for the Titromatic analyser, manufactured by Electronic Instruments, Ltd., Richmond, Surrey, valued at over $10,000, has been received from the Aluminum Company of Canada, Ltd. The first Titromatic analyser to be supplied to North America was delivered a few months ago to the Esso Refinery, Baton Rouge, Louisiana, U.S.A.

The Canadian requirements created a particularly difficult problem because of the corrosive nature of the reagents required in the assay of the aluminium content of ore. Special arrangements for flushing and mechanically brushing the electrodes after each titration were made. This was possible because the fundamental design of the Titromatic analyser is such that it permits great versatility and equipment for almost any analytical problem involving titration can be made from a suitable assembly of standard parts.

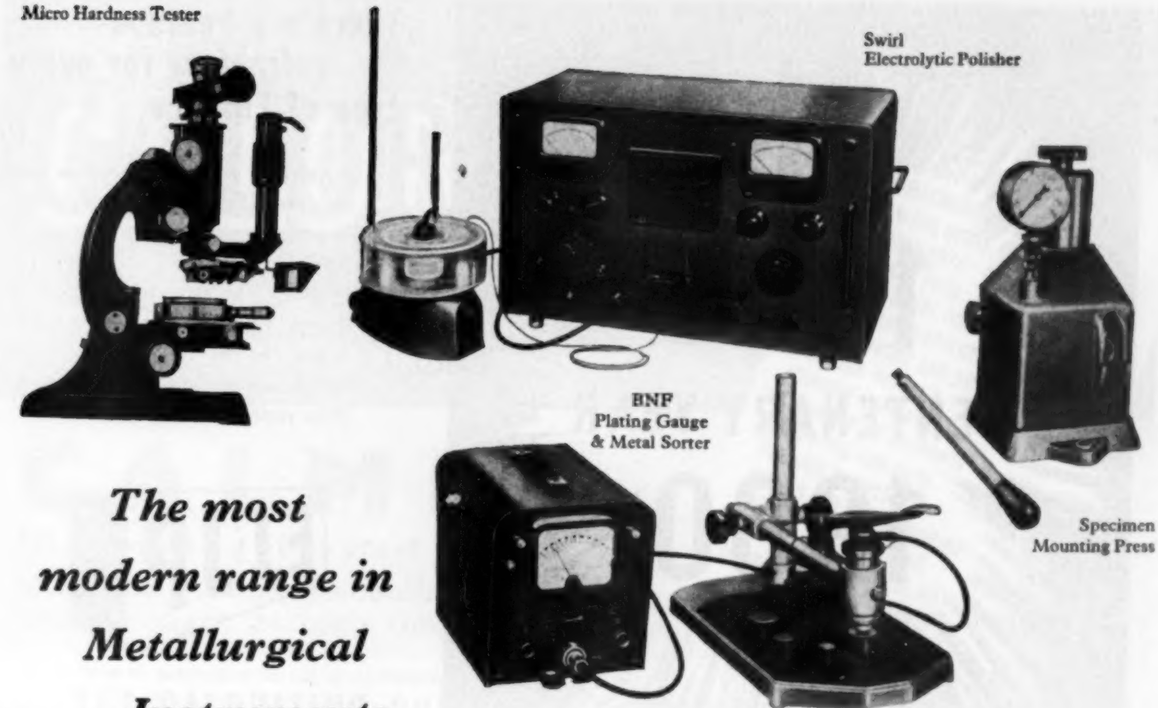
The analyser is intended to assay the aluminium content and the free alkali of five separate ore plant streams. To perform this operation, it automatically carries out a double end-point titration with two added reagents on each of the five streams. The ore liquor is highly corrosive and all taps, vessels and piping in contact with it are P.T.F.E. lined. To avoid scale formation, the complete sampling system is flushed frequently with water and acid. After every titration, the electrode system is cleaned by mechanical brushing under alternate sprays of acid and water. It was only after the chemist in charge of the Canadian process had spent three weeks in testing and evaluating the new equipment at the Richmond factory of E.I.L. for all the requirements likely to be made upon it, that the company placed the order.

Shrink Fitting with Liquid Nitrogen

A four-ton guide stalk on a 12,000 ton trimming and bending press has been shrunk by the use of liquid nitrogen before being fitted into its housing. The operation, which took place in Glasgow, resulted in a perfect fit without distortion. This method, using 45,000 cu. ft. of liquid nitrogen, was adopted in preference to expansion by heating of the cast steel housing into which the guide stalk was to fit. To have used the older method would have meant heating the casting for up to eight hours, during which time distortion would almost certainly have taken place. By using liquid nitrogen, manufactured and supplied by British Oxygen Gases, Ltd., a saving of four hours was obtained, and there was no distortion to either component.

British Metal Sinterings Association

The Metal Powder Industries Federation of New York has announced the election of the British Metal Sinterings Association as an overseas co-operating association, thus officially linking these organisations in an international programme of co-operation in powder metallurgy. The British organisation is a trade association for contract powder metallurgy parts manufacturers. As a member of the Federation, it will now be possible to develop a programme of technical exchange and close co-operation in standardisation activities. The Association is represented in the Federation by the Secretaries, Peat, Marwick, Mitchell and Co.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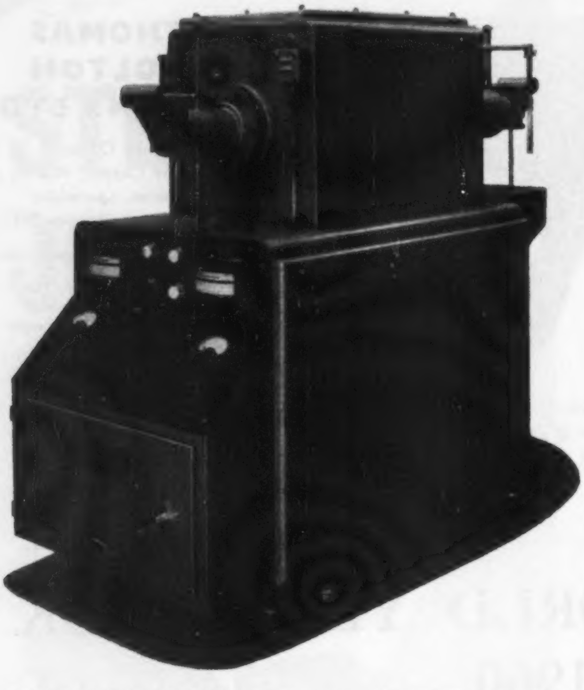

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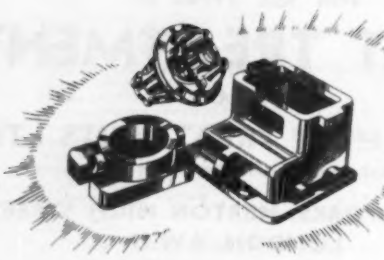

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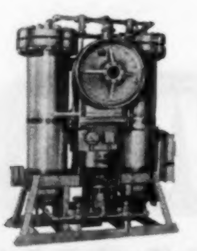

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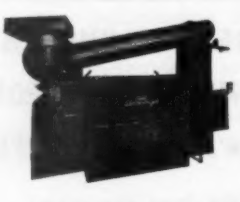

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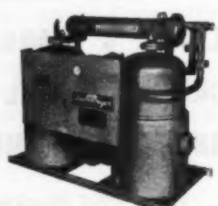

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1 To take responsibility for initiating and developing metallographic techniques which are required for the examination of treated materials, and to be responsible for the application of recent and novel methods of structure examination. The successful applicant should be of graduate or A.I.M. level, and it is expected that he will eventually lead a team on this work. A four figure salary will be paid to suitable applicants.

2. A physicist with an electronic or electrical engineering interest is needed for a team which will be engaged on the application of electrical discharge methods in metal treating processes. Applicants should be of graduate level but consideration will be given to men with suitable background and experience.

Apply in writing, stating age, qualifications and experience to the

PERSONNEL MANAGER

JOSEPH LUCAS LIMITED

Great King Street, Birmingham, 19, quoting reference PM/GR/434.

SITUATIONS VACANT—*continued*

Royal Technical College, Salford.
DEPARTMENT OF
MECHANICAL ENGINEERING

Applications are invited for the following academic appointments in METALLURGY in this COLLEGE OF ADVANCED TECHNOLOGY :—

READER in METALLURGY : £1,800 rising to £2,100 per annum. Exceptionally, a higher maximum may be fixed. Applicants should have good academic qualifications in metallurgy and experience showing proven ability in fundamental or applied research in this subject. The person appointed will be responsible for carrying out research and for developing advanced studies in this subject.

SENIOR LECTURER or LECTURER IN METALLURGY : £1,550 rising to £1,750 per annum or £1,370 rising to £1,550 per annum. Exceptional applicants may be considered for appointment as a PRINCIPAL LECTURER in the salary range £1,750 rising to £1,900 per annum. Applicants should have an honours degree in metallurgy and either teaching, industrial or research experience. The person appointed will be expected to specialise in the teaching of metallurgy to engineers and actively to carry out research in metallurgy.

The Department is at present responsible for most of the work in metallurgy in the College and the vacancies offer considerable scope to the persons appointed.

Further particulars and forms of application may be obtained from the Registrar, Royal Technical College, Salford 5, Lancs., to whom applications should be sent by Wednesday, 20th April, 1960.

R. RIBBLESDALE THORNTON,
Clerk to the Governors.

MIDDLESEX COUNTY COUNCIL
Education Committee
BRUNEL COLLEGE of TECHNOLOGY
Woodlands Avenue, Acton, W.3.
Department of Chemistry
Metallurgy Division
SENIOR LECTURER IN
METALLURGY

to commence on 1st January 1961. Duties will include the teaching of metallurgical subjects in courses for the Diploma in Technology and other courses leading to professional qualifications. Some special experience in the physico-chemical and thermodynamical field in relation to metallurgical extraction processes would be a recommendation. There will be opportunity for research. Candidates must hold a good honours degree in Metallurgy and have some experience in metallurgical work—teaching, industrial or research.

Salary within the range £1,588–£1,801 per annum.

Additions above the minimum of the scale may be granted for approved time spent in teaching, industry, professional work or research.

Application forms are available from the Principal and should be returned by Monday 25th April, 1960.

C. E. GURR, M.Sc., Ph.D.,
Clerk to the Governing Body.

MACHINERY PLANT & ACCESSORIES FOR SALE

PURE BERYLLIUM FOIL. 0.005 in. thick. Elgar Trading Ltd., 23, Salisbury Grove, Mytchett, nr. Aldershot. Tel. : Farnborough-Hants 2634.

CLASSIFIED ADVERTISEMENTS

SITUATIONS VACANT—*continued*

IMPERIAL CHEMICAL INDUSTRIES LIMITED
Billingham Division
require
METALLURGISTS

for work in the Division's metallurgical laboratories. The work is varied covering a wide range of metallic materials and fabrication processes used in the construction and maintenance of chemical plant.

Candidates should be aged thirty or under and should be Licentiates of the Institution of Metallurgists or have a Higher National Certificate or equivalent in Metallurgy.

The appointments are pensionable, there is a Profit-Sharing Scheme and assistance can be given towards house purchase and removal expenses for married men.

Write, giving brief details of age, qualifications and experience, quoting reference S/T2, to :—

ICI

The Staff Manager,
Imperial Chemical
Industries Limited,
Billingham Division,
Billingham,
Co. Durham.

IRONFOUNDING TECHNOLOGISTS

THE BRITISH CAST IRON RESEARCH ASSOCIATION REQUIRES MEN WITH TECHNICAL EXPERIENCE IN THE IRONFOUNDING INDUSTRY AND THOROUGH TRAINING IN METALLURGY OR ENGINEERING FOR APPOINTMENTS IN ITS DEVELOPMENT DEPARTMENT.

The Department provides an advisory service to Association members which covers investigational and advisory work on foundry production methods, metallurgical and general foundry problems, and engineering problems involving use of castings.

The posts offer excellent opportunity for extensive experience in all types of ironfoundries throughout the country. Remuneration will depend on age, experience and qualifications, but will be substantial and equal to salaries likely to be paid by industry.

The Association's laboratories are in pleasant rural surroundings, near Birmingham. Private daily coach service available from Birmingham or Redditch. A contributory pension scheme is in operation. Forms for application from the Manager, Development Department, British Cast Iron Research Association, Alvechurch, Birmingham.

All applications treated in strictest confidence

AEI

ASSOCIATED ELECTRICAL INDUSTRIES (MANCHESTER) LTD.
ANALYTICAL CHEMISTS

Associated Electrical Industries (Manchester) Ltd. have vacancies in their Research Department in Trafford Park for Analytical Chemists with experience of inorganic and metallurgical work, or with general experience including paints, lubricants and fuels, for laboratory handling a wide range of materials.

Please write for application form quoting reference S.14 to :—

Personnel Manager, Associated Electrical Industries (Manchester) Ltd., Trafford Park, Manchester, 17.

SITUATIONS VACANT—*continued*

CHEMISTS AND METALLURGISTS
required for
RESEARCH AND DEVELOPMENT ON AIRCRAFT AND ENGINEERING MATERIALS

The work includes :—

a. Development on Plastics, Rubbers, Lubricants, Adhesives and other Organic Materials, Electro-Chemistry, Corrosion and special Analytical Methods.

b. Development on Medium High Tensile Alloy and Non-Corrodable Foundry Steels and Techniques.

c. Development of Wrought Heat and Corrosion Resistant Metallic Materials and Ultra High Tensile Steels.

d. Static and Dynamic Mechanical Testing of Materials.

e. Liaison with Design and Production Departments and investigation of Production and Service failures.

Applicants should be Graduates or have equivalent qualification. Previous experience in the fields of work desirable but not essential. Please send full details to the Personnel Officer, Fairey Aviation Limited, Hayes, Middx.

BICC
METALLURGIST

RESEARCH METALLURGIST required in the Shepherds Bush Research Laboratories of British Insulated Callender's Cables Limited for work on investigations dealing with the processing and development of electrical conductor and resistance materials. Some industrial experience is desirable, although this need not necessarily be in the fields mentioned.

Five day week ; pension fund.

Applications giving details of age, qualifications and experience should be made to Personnel Officer, BICC Limited, 28 Wood Lane, London, W.12.

WAR OFFICE requires METALLURGIST/CHEMIST in Durham for work concerned with quality control of production materials and metallurgical/chemical processes involved in manufacture of cartridge cases, shell and anti-tank shot. Quals.: Hons. degree in either Metallurgy or Chemistry or A.I.M. or equiv. Wide experience of cold and hot working of materials such as 70/30 brass, steel and aluminium alloys. Salary: £1,245–£1,680 per annum. Opportunities for establishment. Forms from Ministry of Labour, Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting reference F.142/0A. Closing date, 14th April, 1960.

DELORO STELLITE LTD., manufacturers of cutting steel and high temperature alloys, require the services of a fully competent analyst in its chemical laboratories. Particular consideration will be given to candidates possessing a wide experience of metallurgical analysis. Good working conditions and prospects in expanding organisation. 5-day week, superannuation and group assurance schemes in operation. Please apply to :— Personnel Manager, Highlands Road, Shirley, Solihull, Warwickshire.

SITUATIONS VACANT—*continued*

THE MANCHESTER COLLEGE
OF SCIENCE AND TECHNOLOGY
(Faculty of Technology in the
University of Manchester)
Appointment of
LECTURER IN METALLURGY

Applications are invited for the post of Lecturer in Metallurgy with the title and status of Lecturer in the University of Manchester. Salary according to qualifications in the scale £900 × £50–£1,350 × £75–£1,650. Superannuation under the F.S.S.U. Family allowances. Candidates should have specialised knowledge in at least one of the following fields and must be prepared to undertake or supervise research for which there are excellent facilities : Metallurgical Analysis, Refractories, Non-Ferrous Extraction, Physical Metallurgy.

Conditions of appointment and application form may be obtained from the Registrar, The Manchester College of Science and Technology, Manchester, 1, to whom applications must be returned by Saturday, 2nd April, 1960.

AIRCRAFT-MARINE PRODUCTS (G.B.) LTD. require a METALLURGIST who will :—

(a) Advise on the correct use of steels for metal stamping dies, compression-joint forming tools, etc.

(b) Monitor the quality of production samples of such steels and also of a limited range of non-ferrous alloys.

(c) Form part of a team carrying out tests and research on electric contact and electrical connections. Ability to assist the Head of the Department in supervising such tests would be an advantage.

The post would be suitable for a young graduate with a few years practical experience of steels, and offers good salary and prospects in a rapidly expanding company.

Superannuation scheme and other benefits. Apply giving full details to :

Manager—Research and Development
Aircraft-Marine Products (G.B.) Ltd.,
Amplo House,
87–89 Saffron Hill,
London, E.C.1
or phone CHAncery 2902

METALLOGRAPHIC MOUNTING MEDIUM

N.H.P. Mounting Plastic, a cold-curing acrylic resin, permits the rapid mounting of metallographic specimens without the aid of heat or pressure.

It calls for the minimum of equipment and skilled attention and yet gives a close, tight mount, capable of a high degree of edge preparation.

Used routinely by many leading manufacturers. Full details on request to the makers: NORTH HILL PLASTICS, LTD. MANLEY COURT, LONDON, N.16.

MACHINERY PLANT & ACCESSORIES WANTED

2—Batch Type Electric Furnaces.
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1—Forced Air Circulating Tempering Furnace. 20 k.w.
1—Rotary Type Electric Furnace:
20/30/k.w.

Full details and particulars to Box No. MR77.
"METALLURGIA" 31, King St. West, Manchester 3.

INDEX TO ADVERTISERS

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